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Semi-Popular Articles

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Age-Old Resins of the Mediterranean Region and Their Uses

Many of the resins or resin-like substances of the Mediterranean and adjoining regions have been exploited by man from the earliest times. Good examples are myrrh and frankincense with their Biblical associations and use in incense. Others were much valued for medicinal purposes. Some were used by the Egyptians in embalming, while mastic and sandarac have long been valued for special paints and varnishes. In the Middle Ages the famous Italian painters made use of them, the actual formulae used being sometimes closely guarded secrets.

F. N. HOWES

Principal Scientific Officer, Royal Botanic Gardens, Kew, England

Introduction

Gums and resins are kindred groups of economic plant products, both being natural secretions of plants. The essential difference between the two groups is that the true gums are more or less soluble in water or swell to a jelly-like mass with water but remain insoluble in organic solvents, whereas resins are unaffected by water but are soluble, more or less, in various organic solvents.

Some plant exudations consist of a mixture of both gum and resin and are commonly termed " gum-resins ". Other exudations, usually of a more or less soft consistency, consist of a mixture of gum and resin plus essential or volatile oil. For these the term " oleo-gum-resin " is employed. Very frequently oleo-gum-resins are pleasantly fragrant, owing to the presence of the essential or volatile oil in some quantity. This may have accounted for their popularity, in part at least, with the Ancients. Some were greatly esteemed for medicinal purposes. In general their use in medicine has very much declined.

The Mediterranean region is notable for the number of different oleo-resins or oleo-gum-resins that are produced by the plants of that area. This may be due to climatic factors, for it is known that a dry type of climate favours the production of both resins and gums (13).

Mastic

This resin, restricted in its production to the eastern Mediterranean, may vary in colour and appearance according to grade but is generally a pale yellow and in small tears, usually ¼ to $^{5}/_{16}$ inch in diameter. These are clear and glassy when fresh, also brittle, breaking with a conchoidal fracture. Not infrequently cylindrical pieces occur which may be up to ¾ inch long and ⅓ inch wide.

The main source of supply of the resin has always been the island of Chios in the Aegean. At one time the Greek emperors held a monopoly of the resin. In the Middle Ages the island was noted for its mastic. The resin was mentioned by Theophrastus who lived in the fourth century before the Christian era, so its use goes back to very early times (7).

The age-long use of mastic in Mediterranean countries was as a masticatory to sweeten the breath, being of a sweet smelling or aromatic nature itself. It was also considered to preserve the teeth and gums. As mastic is used at the present time in the preparation of chewing gum, its early use as a masticatory may be said to have been maintained but in modern form. At one time it was freely used medicinally and also in flavouring alcoholic beverages and cordials. Its use in medicine is now more restricted, but it does enter into the preparation of various pharmaceutical products, also perfumes (13).

The main use of mastic today and for many years past has been in the manufacture of pale, high grade varnishes required for special purposes, such as the protection of pictures in both oil and water colours. So employed it has the great advantage of being easily removed, either by solvents or by friction, without injury to the picture. The gelatinous material megilp, so well known to artists and valued on account of its good working qualities, consists of mastic, turpentine and linseed oil. It is named after its inventor—McGuilp (11).

In the island of Chios where mastic has so long been regularly and systematically collected the industry is said to be now well organised. An informative and most comprehensive account of the industry has recently been given by Davidson (9), who visited the island for the purpose of studying the mastic industry in 1947. The following remarks are largely drawn from his account.

The tree or shrub cultivated for mastic in Chios is that known botanically as *Pistacia lentiscus* L. var. *chia*. It is evergreen and dioecious, and normally reaches a height of only six to ten feet, but may be taller. Although normally bushy it is usually trained as a standard with a solitary main stem. The usual method of propagation is by cuttings (*in situ*), and it is said that it is the male plant that is always propagated because the female yields an inferior mastic. Among the growers or producers of mastic in Chios a number of local varieties are recognised. These are distinguished from one another by the size or shape of the leaves and by other characteristics as well as the quality of the mastic yielded. In establishing a grove or plantation the cuttings, a metre or so long, are spaced at intervals of three to four metres in lines four to five metres apart. In the fifth or sixth year the young trees may give their first small yield of mastic. They are pruned periodically to preserve a good shape. Cultivation and feeding with animal manure are practised. Good results have also been obtained by green manuring and by the use of artificial fertilizers.

A peculiarity about the mastic industry in Chios is that it is limited to the southeast corner of the island where the tree thrives and yields its resin at various altitudes up to 500 metres, the average annual rainfall being about 29 inches. It is said that when grown in other parts of the island, or in adjoining islands, the tree may grow normally and flourish but does not yield a "gum" with true mastic characteristics. The suggestion has been made that the geological nature of the southeastern part of the island may have a bearing on the matter.

Collection of mastic in Chios is now limited by law to the three-month period July 15–Oct. 15 in order to avoid collection of inferior "winter mastic", known locally as "kokkologi". Tapping is carried out with a small tool resembling a carpenter's gouge. The shallow incisions made may be on the larger branches as well as on the main stem. Tapping is done periodically for about six weeks. The mastic which oozes from the wounds either forms tears on the bark or falls to the ground. Before tapping, the

ground under the trees is levelled, beaten hard and sprinkled or covered with white earth. This causes the mastic which falls to retain a good colour. The tears set fairly hard about a fortnight after they have formed.

During the collecting season the peasants store the mastic collected in their homes, spread out in a single layer in some convenient place. When all has been collected it is cleaned, washed and graded for size and quality, special names being used for different grades (4).

With regard to yield it is stated (Davidson) that a five- to six-year-old tree will yield only five drams. A ten-year-old tree may yield ten drams. This increases to 100–150 drams at the age of 50 or 60 years. Exceptional trees have yielded 400 drams a year, but the usual yield of middle-aged trees is 50–60 drams (4).

Sandarac

This resin is obtained from *Tetraclinis articulata* Mast., a coniferous tree that occurs in some of the mountainous areas of northwest Africa and also to some extent in Spain (Armeria) and in Malta. The resin is collected by the natives and shipped mainly from Mogadore, Casablanca and Nazagan, "Mogadore sandarac" being a trade term in common use at one time.

The resin is pale yellow and usually in tears ¼ to ¾ inch long. Sometimes these are cylindrical or stalactitic in form or they may be united into small mases. The tears or fragments, generally covered with yellowish dust, are brittle, and the broken surface clear and vitreous. Sometimes small insects may be seen imbedded in them. The odour and taste are terebinthinate or suggestive of turpentine, and this is intensified on warming. About one percent of volatile oil is present, and traces of a bitter principle. When chewed this resin does not agglomerate into a plastic mass as do mastic and most other resins but merely breaks up into a sandy or mealy powder in the mouth. The resin is easily powdered (17).

Like mastic sandarac was known to the Ancients and to peoples of the Mediterranean in the Middle Ages, being used medicinally and as a picture varnish. It is still employed to some extent medicinally. In pharmacy its chief use is in the preparation of pill varnishes, and it is sometimes utilized in alcoholic solution on cotton wool as a temporary filling for teeth. The resin is completely soluble in alcohol and in ether; partly soluble in chloroform, carbon bisulphide and oil of turpentine.

The main use for sandarac is for varnishes of special types. With alcohol it yields a hard white spirit varnish which is prone to be brittle unless mixed with other resins. The resin has been much used as a metal varnish and gives good lustre in thin coats. It has also been used as a leather and paper varnish, being often employed for indoor labels. The gloss may vary according to the nature of the solvent used (11). In bygone days sandarac was used in powdered form as pounce for preparing the surface of parchment for writing.

The tree yielding sandarac belongs to a monotypic genus allied botanically to *Callitris* and *Widdringtonia* but differing from them in its four-ranked leaves and its flattened *Thuja*-like divisions of the branchlets. Its small rounded cones (⅓ to ½ inch in diameter) are deeply grooved and composed of four scales. Six seeds are usually produced by each cone. The tree is an evergreen and normally of pyramidal habit, reaching 40 to 50 feet in height with a trunk two to four feet in girth. In its natural habitat it is often exposed to long periods of drought and is to be seen on poor soil or almost pure rock where little other vegetation can exist. It is common in some of the mountainous areas of Morocco

and Algeria where it is important for timber quite apart from the resin. In Morocco there are extensive forests at the higher altitudes in the central and southwestern parts of the country (13).

The wood is fragrant, yellowish brown or reddish, and is hard and short grained. Sometimes it is beautifully marked as in bird's-eye maple. The wood has long been popular for fancy cabinet work and for furniture. It is said to be the "citrus wood" of the Romans who preferred it to all other woods for roofing temples.

The bark of the living tree contains numerous schizo-lysigenous cavities which are full of the liquid resin. Some of the resin collected by the natives appears on the surface of the trunk as a result of natural exudation, and some is obtained as a result of making incisions in the bark. The secretion gradually hardens and is finally picked off when quite hard and dry.

Australian sandarac, which is altogether a newer and more recent product, is obtained from several species of the allied genus *Callitris* in Australia, the trees being commonly known there as the "cypress pines". The resin is very similar to ordinary or African sandarac, both in its physical and chemical properties and in the uses to which it may be put. The product appears to have been mainly consumed in Australia and but little exported so far. The most important species are considered to be *Callitris calcarata* R.Br. ("black cypress pine"), *C. glauca* R.Br. (Murray River Pine) and *C. verrucosa* R.Br. (13).

Dragon's Blood

This fanciful name has been employed for a number of different resins that are of a dark red colour and used either medicinally or for varnishes. Most of the dragon's blood that enters commerce at the present time is derived from climbing jungle palms, species of *Daemonorops*, from the Malayan region. Originally, however, the name was used only for the dragon's blood of Socotra, derived from *Dracaena cinnabari* Balf., a liliaceous palm-like tree that occurs on that island (8).

Socotrine dragon's blood is known to have been used by the peoples of the Mediterranean from very early times and constituted an article of trade with them. It may therefore be fitting to refer to it here, although it is not one of the resins that are produced within the Mediterranean basin. Some of the early writers, among them Dioscorides and Pliny, referred to it. It was held in high esteem for its medicinal or its alleged medicinal properties by the Greeks and Romans. The Arabs also made use of the resin in this way and knew it as "dam-ul-akh-wain", a name which it retains among them at the present day (13).

In European medicine dragon's blood was formerly used in dysentery and diarrhoea, and as an astringent in tooth powders. Other uses are for colouring mahogany-coloured varnishes and for staining marble.

A trade term at one time in use for Socotrine dragon's blood was "Zanzibar drop", the reason for this being that the resin often found its way to Bombay or Zanzibar before being exported to Europe.

Frankincense

The use of frankincense or olibanum, as it may also be called, goes back to a very early period, and there are numerous references to it and to incense, of which it formed an essential ingredient, in the Bible. As typical of the great esteem in which frankincense was held in Biblical times, the memorable gifts presented by the Magi to the infant Saviour may be called to mind. Herodotus relates how the Arabians paid to Darius, King of Persia, an annual trib-

ute of 1000 talents of frankincense. It has also been established that many centuries before Christ the Phoenicians and Egyptians carried on trade in frankincense. In the temple of Dayr el Bahri in Upper Egypt there are said to be paintings illustrating the trade carried on between Egypt and a country called Pount, as early as the 17th century B.C., in which representations of frankincense or bags of frankincense occur, also of frankincense trees planted in tubs or baskets being conveyed by ship to Egypt. The country Pount is considered to have been what is now the Somali coast, together with a portion of the opposite Arabian coast (7).

With regard to the early use of incense outside the Mediterranean region, it is an interesting fact that the Arabs in their trade with the Chinese, which existed as early as the tenth century, exchanged frankincense, myrrh, dragon's blood and storax, all these commodities being imported from the West into China (7: 12).

Frankincense is obtained from species of *Boswellia*, mainly *B. carteri* Birdw. and *B. frereana* Birdw. The genus *Boswellia* belongs to the family Burseraceae, well known for its fragrance, and consists of about a dozen species of small trees or shrubs that occur mainly in dry parts of northeast Africa and southeast Arabia. It would seem that for some time past frankincense has been collected only in Africa and not in Arabia (5). Ducts occur in the bark and other parts of the plant, and these contain the fragrant oleo-gum-resin. When this exudes, as a result of injury or wounding, it is at first a thin milky fluid but soon thickens and hardens to a solid or semi-solid consistency.

In Somaliland the species mainly exploited for frankincense are *Boswellia carteri* Birdw. and *B. frereana* Birdw. The frankincense-yielding or potential frankincense-yielding areas are extensive and generally consist of rough, inhospitable or mountainous country which renders collection difficult. Frequently only the more accessible trees are tapped, while those in the more remote or difficult situations are neglected. As the resin is readily spoiled by rain, collection is carried out only in the dry season. Even so as the resin is transported to the coast or is stored prior to shipment, " blocking " of it commonly takes place, i.e., the tears become consolidated, which results in a lower price (6).

Tapping is carried out about the end of March or early April and may go on for five or six months. It may be effected by scraping away portions of the bark instead of making incisions. For this a special tool, termed " mengaff ", may be used. It resembles a double scalpel with a sharp and a blunt end. The sharp edge is used in the actual decortication, and the blunt end in assisting to remove the resin when it is harvested. The first collection of the resin may take place about a fortnight after tapping when the globular pear-shaped or club-shaped tears are removed. Subsequent collections are made every few weeks, the wound being freshened each time.

An idea of the attitude of the natives towards the tree in Somaliland and the method of regeneration is afforded by the following remarks: " Reproduction takes place by seed. The seed falls from the parent plant on to the rocks below, penetrates into one of the innumerable openings that the rocks present, finds there a little earth borne by the wind, germinates, puts out rudimentary leaves and a fleshy rootlet. For some time the young plant has a precarious existence, then it gradually gains strength and extends its root or enlarges its sucker according to the circumstances of its situation. . . . Certainly the natives do not concern themselves, and have never concerned themselves with the propagation of the precious plant—' Allah takes

thought for everything, ours not to understand.' And with that convenient tribute to divine providence they are dispensed from any further trouble in the matter. It appears indeed that a descendent of the Osman Mahmud once tried to transplant some incense plants into open ground near the wady of Botiala, removing them from the mountain with great care, and with portions of rock adhering to their suckers. The plants, according to the story told by an aged chief, after a few years of exuberant growth came to grief in the waters that flooded the wady as a result of some exceptionally heavy rains. Allah had his revenge" (10).

The frankincense of commerce is usually pale yellow but sometimes has a reddish or greenish tinge. The fragments or tears vary much in size and are brittle and easily broken with the fingers. Their odour is of course fragrant. When chewed they have a slightly bitter taste and form a plastic mass in the mouth. The composition is approximately 60% to 70% resin, 27% to 35% gum and 3% to 8% volatile oil.

The main use of frankincense today is in the manufacture of incense, for which substance it is regarded as an essential ingredient. Other uses are in fumigating powders and pastilles, but in most countries it is no longer an ingredient of medicine.

Other species of *Boswellia* are known to yield fragrant resins, although not of commercial importance. In West Africa *B. dalzielii* Hutch., also a small to medium-sized tree with sweet smelling flowers and common in some areas, yields an aromatic resinous exudation. This is collected by the natives and burned to fumigate clothing or to drive away flies and mosquitoes from dwellings (13). In dry hilly areas of northern India *B. serrata* Roxb. yields a fragrant oleo-gum-resin ("Indian olibanum") which has been exported and may be used for incense. Resins of the frankincense type are yielded also by *B. ameero* Balf. in the island of Socotra and by *B. bhaudajiana* Birdw. and *B. papyrifera* Hochst in northeast Africa.

Ladanum

Ladanum or labdanum, a fragrant resinous substance used mainly as a fixative in perfumery and in scenting certain kinds of soap and tobacco, is obtained from various species of *Cistus* or "rock rose" in the Mediterranean region.

The ladanum of Spain, Portugal and France is considered to be mainly derived from *Cistus ladaniferus* L. and that of Crete from *C. creticus* L., an allied species. *Cistus ladaniferus* is an evergreen shrub three to five feet high with somewhat clammy branches, owing to the presence of resin. It is often grown as an ornamental on account of its handsome flowers which are mainly white and large—three to four inches across. The petals possess a crimpled margin and have a blood-red spot near the base. There is, however, a form with pure white flowers with no red spot at the base of the petal. This "rock rose" has the largest flowers of any of the many species cultivated out-of-doors in the British Isles, but it is not so hardy as some of the other species. The plant is native to southern Europe and North Africa.

In Spain the common method of obtaining ladanum is to boil the twigs, collected in spring and early summer, usually between March and July, and skim off the resin that comes to the surface. However, solvent extraction processes may be used, as in France, and these are claimed to yield a superior product with less loss of aroma (1). Ladanum commonly comes into commerce in the form of dark blackish-brown to greenish lumps. Extraneous matter is often present in some quantity,

or it may be adulterated with other resins. Sometimes the odour is faintly ammoniacal.

In Crete, where *Cistus creticus* is the species mainly exploited, unusual methods of collecting the resin may be practised. A rake-like frame bearing two long leather straps or thongs is used to whip the plants, which causes the odorous resinous substance to stick to the thongs. It is then scraped off and rolled into thick sticks or lumps for the market. At one time it was said to be gathered from the beards of goats that had been browsing on the plants, also by driving sheep to and fro among the bushes and then combing the resin from their fleeces. *Cistus creticus* is smaller than *C. ladaniferus*, being usually about two feet in height. Its flowers are also much smaller, purple or purplish, with the petals yellow at the base.

Ladanum is reputed to be much used in Turkey. The odour varies a good deal with different botanical or geographical sources. It may be of the heavy oriental type or powerful and sweet with something in common with ambergris, or it may have the detrimental ammoniacal odour. It is much valued in certain classes of perfumes and as a fixative. Ladanum is the nearest approximation to ambergris in the Vegetable Kingdom. It is used in the preparation of artificial ambers and as a fixative in perfumes of the following types—carnation, hyacinth, lavender, lily, narcissus, patchouli, rose, reseda, trifle, verbena, violet, wallflower. Ladanum also has a place in fumigating preparations, especially in cone pastilles, the popular form. In soap perfumery it is perhaps favoured most for toilet soaps of the lavender and sandalwood classes.

Asafoetida

Asafoetida is one of several resins derived from the family Umbelliferae which is so well represented in the vegetation of the Mediterranean region. The resin has undoubtedly been used medicinally from very early times. Some consider that the substance which the Ancients called "laser" was actually asafoetida, but others are inclined to question this. Laser was one of the substances from India or Persia on which duty was levied at the Roman custom house of Alexandria in the second century. The word "hingu", which occurs in many Sanskrit works, especially in epic poetry, is also considered to refer to asafoetida. Asafoetida was known to the Persian and Arabian geographers, and to travellers of the Middle Ages. Like many other commodities it found its way into western European commerce during the Middle Ages through the trading cities of Italy. In the 13th century the "Physicians of Myddfai" in Wales considered asafoetida to be one of those substances which every physician "ought to know and use" (7).

Asafoetida is collected from the living root of *Ferula foetida* Regel, *F. rubricaulis* Boiss. and probably other species that occur in Persia or Afghanistan. The method of collecting varies in different localities. A common technique is to scrape away the soil from the top of the large fleshy root and to make incisions in it, or the top part may be cut away. After the resinous juice that exudes has dried it is collected and eventually finds its way to the market. Large schizogenous resin canals are very abundant in the root. In the Fars district of Persia where the asafoetida plant reaches seven to ten feet in height and is termed "anghuzeh", the main stem of the plant may be severed at intervals nearer and nearer the base and the resin obtained that way. The asafoetida from this area goes mainly to Bombay via Persian Gulf ports, such as Bundar Abbas (17). From Bombay it is exported to European and other countries.

Commercial asafoetida is either in the

form of tears or in an agglomerated mass, the latter being the more common form and the form most likely to contain impurities, such as fragments of root or stems, fruits, earth, small stones or other matter. The tears may vary from a quarter of an inch or less to over an inch in diameter. They may be yellow, grey or reddish-brown. The resin softens markedly on warming and powders best if cooled first. It has a strong alliaceous odour and taste. Good samples consist of approximately 40% to 64% resin, 25% gum and 10% to 17% volatile oil. Medicinally asafoetida is employed as a carminative in flatulence and as a sedative in nervous disorders (in hysterical conditions); also as an expectorant in chronic bronchitis. The resin or drug is often used in veterinary work. It is said to be a constituent of certain sauces.

Galbanum

This oleo-gum-resin is so similar to asafoetida that it may well be considered with it. In the first place it is the product of species of *Ferula* and is collected in Persia in some of the same areas as asafoetida. The method of collecting is also similar, a portion of the root being laid bare and incisions made in it, or the top cut off to induce the resin to flow. Slices of the root may be removed at intervals. Like asafoetida commercial supplies reach western markets mainly via the Persian Gulf ports and Bombay. Some of the resin collected is the result of natural exudation, in many instances due to insect attack.

Although there is still some doubt as to all the species of *Ferula* that may yield asafoetida or galbanum, it is considered that galbanum is derived mainly from *F. galbaniflua* Boiss. and possibly *F. schir* Boiss.

Galbanum, as marketed, appears either in tears or in an agglutinated mass with impurities in the form of earthy matter or vegetable debris. The tears are brownish and usually smaller than those of asafoetida. They are also softer—soft enough to be flattened between the finger and thumb. The odour is pleasant but the taste somewhat unpleasant and characteristic. The composition is variable with different samples, but is usually within the following range—resin 50% to 70%, gum about 20%, volatile oil 5% to 20%. When used medicinally galbanum may be employed as a stimulant expectorant in chronic bronchitis or externally in the form of plaster for inflammatory swellings.

Ammoniacum

There are two main forms or varieties of this oleo-gum-resin which has medicinal uses very much the same as asafoetida and galbanum, although little used at the present time. These two forms are Persian ammoniacum and African ammoniacum. The former is the better known and the one that generally enters commerce, being derived from *Dorema ammoniacum* D. Don and probably other species such as *D. aucheri* Boiss. that occur in Asia Minor. African or Moroccan ammoniacum, on the other hand, although very similar, is derived from species of *Ferula*. The ammoniacum known to the Ancients and referred to by Dioscorides and Pliny and succeeding Greek and Latin writers on medicine is believed to have been that obtained from *Ferula*.

Persian ammoniacum has also been known from fairly early times and is reputed to have been referred to by a Persian physician in the tenth century who called it "ushak", a name which it still retains in Persia. *Dorema ammoniacum* is a perennial plant with the main or flowering stem reaching six to eight feet in height. It has large compound leaves and is covered in the young state with fine hairs giving it a greyish look. It occurs over a wide area in Asia Minor and is common in some localities,

especially in central Persia. It is reputed to be very prevalent in the area between Ispahan and Shiraz. The resin when collected is largely despatched to Ispahan, whence it passes via the Persian Gulf ports to Bombay.

The stem of the plant contains the resinous milky juice which flows out with the slightest puncture. It may solidify next the wound or puncture, or run down the stem. The resin collected is mainly the result of natural exudations caused through the punctures of insects, chiefly beetles. The exudations appear and are collected mainly in May and June.

Like asafoetida and galbanum, ammoniacum appears in commerce in two forms, as tears or in lump (agglutinated) form when it is apt to contain impurities such as pieces of stem, fruits or earthy matter. The tears are yellowish, more or less round, and may be anything up to about an inch in diameter. The tears are harder than those of galbanum but soften on being warmed. The odour is characteristic and the taste bitter and acrid. Ammoniacum contains up to 6% of volatile oil, 60% to 70% of resin and about 20% of gum.

Sagapenum and Opopanax

These two resins of the Mediterranean region or Asia Minor do not normally enter commerce and have not done so for many years, although they appear to have been well known and freely used in earlier times. In mediaeval pharmacy sagapenum was frequently called "serapinum" (7). As it is frequently mentioned by the older writers, it must have been fairly plentiful. The botanical origin is not known with certainty but is believed to be species of *Ferula* (possibly *F. persica* Willd. and *F. szowitziana* DC.) that occur in Persia and Arabia. Sagapenum is described as possessing a bitter, nauseous taste, and an odour more aromatic than but not so strong as that of asafoetida. Its uses are similar to those of asafoetida and galbanum (19).

Opopanax is described as occurring in hard nodular lumps of an orange brown colour, and to possess a penetrating offensive odour reminiscent of crushed ivy leaves (7). The botanical source has been stated to be *Opopanax chironium* Koch, an umbelliferous plant that occurs in Persia and the Mediterranean region, the resin being obtained by incising the root as with asafoetida (19).

Storax

The name "storax" or "styrax" is used for different products of varying botanical origin. There are two main forms of this resin known to commerce or medicine at the present time, the one a product of the Old World and the other of the New. The Old World product is a balsam or liquid resin derived from the tree *Liquidambar orientalis* Mill. which occurs mainly in the south-west of Asia Minor, while American storax, a similar product, is obtained from the closely allied *Liquidambar styraciflua* L. or sweet gum, a tree native to the United States. Another storax is the solid resin derived from *Styrax officinalis* L., mainly in the eastern Mediterranean area.

Both the liquid and the solid styrax or storax of the Mediterranean region, referred to above, have been known and used since early times and are mentioned by the classical writers. Greek physicians of the sixth and seventh centuries are reputed to have mentioned liquid storax in their writings (18). The early Arabian physicians were also said to have been familiar with it under the name of "miha" ("maya"), and also knew how and whence it was obtained. From an early date storax was shipped to Bombay via the Red Sea and thence to China.

Liquid storax is obtained by injuring or bruising the bark of the tree in early summer. This causes production of the balsam in the bark which is collected in the autumn, and the balsam extracted either by pressure or with boiling water or a combination of both. The liquid storax is a soft viscid resin, opaque and greyish brown, with the consistency of a thick honey. When heated loss of water takes place, the colour darkens and any impurities present sink to the bottom. It has a pleasant aromatic smell and a sharp rather pungent taste. The medicinal uses of storax are similar to those of Peru balsam (*Myroxylon pereirae* Klotzsch) and benzoin (*Styrax benzoin* Dry), but it is now seldom used (13). It is said to be a constituent of Friar's balsam.

In its natural habitat *Liquidambar orientalis* is a handsome tree that may reach 100 feet in height, but is usually considerably smaller. In the relatively cool climate of Britain its growth is very slow but it withstands the winter.

Solid storax from *Styrax officinalis* is said to somewhat resemble benzoin in appearance and to have a fragrant balsamic odour, but the resin has long been scarce, owing to trees having been cut out in many areas. The tree is a native of Greece and Asia Minor up to elevations of 3,600 feet. It is extremely attractive when in flower. In the climate of the British Isles it may be grown only in the most favoured localities or with the protection of a south wall.

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Utilization Abstract

Bark Wax. After many months of development the Oregon Wood Chemical Company, of Springfield, Oregon, began commercial production of wax from Douglas fir bark, formerly burned as a waste product, by means of hot benzene as an extracting agent. The benzene is then separated from the dissolved wax by steam distillation, and the resulting wax is harder than beeswax but not so hard as carnauba. "Already many uses have been found for the wax, including polishes, ski wax, ointments, lubricants, soaps, art and sculpture work, preservatives, and a score of similar applications". (Anon., *Chemurgic Digest 9(7): 9. 1950*).

Alginates in Drugs and Cosmetics[1]

These seaweed products are finding so many industrial uses that not any one listing of those uses appears to be complete.

M. A. LESSER

Technical Editor, Drug and Cosmetic Industry

Introduction

In these days of synthetics it is interesting to see how the alginates, which are natural products, have assumed important roles as valuable industrial raw materials. Sodium alginate or algin, the most important of these compounds, is now being widely used as a thickening agent, emulsion stabilizer and gelling medium in the manufacture of drugs and cosmetics. With well established uses in dentistry, the alginates also offer interesting possibilities in the field of medicine.

The story of the alginates really begins with E. C. C. Stanford's efforts to improve the yield of iodine from seaweed growing along the Scottish coast. While working on this problem, the English chemist became interested in seaweed as a source of useful by-products. In 1883 he extracted an acid substance with unusual gelling properties. He called it "alginic acid" after the Latin word alga, meaning seaweed.

Although progress was slow at first, uses of the alginates have expanded into many industries during recent years. Aside from their use in the drug and cosmetic industry, these materials are also employed in the food industry as stabilizing agents for ice cream and milk mixtures, for thickening jellies, making confectionery and preparing coatings for cheese, meat and other food products. They are also used in textile sizings, finishes and printing compositions. The properties of the alginates are also utilized for creaming latex, for treating paper, in the manufacture of cold water paints, agricultural sprays, boiler compounds, welding rods and in the production of many other items. In many of these applications, sodium alginate competes with vegetable gums, like tragacanth and acacia. A decided advantage of the alginate is its uniformity so that consistent, dependable results are obtained.

Sources

Another advantage of the alginates is an abundant supply of raw materials for their manufacture. The hydrophylic colloidal material is extracted from various species of marine help. In suitable varieties the alginic acid content varies from 20 to 40 per cent of the dried seaweed. On the European and American coasts of the Atlantic Ocean, two species, *Laminaria digitata* Lam. and *Laminaria saccharina* L. (Lam.), are harvested as raw materials, while on the Pacific coast of the United States another species, *Macrocystis pyrifera* ((Turn.) Ag.), is gathered for the same purpose.

Extraction and Production

Although Stanford's original process has been modified and improved in newer methods, the modern extraction principles differ little from those laid

[1] Adapted and reprinted from Drug and Cosmetic Industry **61**: 761. 1947, with elimination of bibliography.

down by the English chemist. In his review of this method, Moncruff says that the preparation of alginic acid is essentially as follows: The seaweed is treated with dilute sodium carbonate solution for 24 hours in the cold. This transforms it into a gelatinous mass which is filtered. The filtrate contains sodium alginate, and, on addition of a strong acid, alginic acid is precipitated. The modern modifications take advantage of newer technics and increased knowledge of colloidal chemistry to produce better, purer and more uniform alginates.

Such improvements, plus continued research, help to explain the rapid growth of the alginates as industrial raw materials. According to Mantell, it is estimated that production in this country is well over 2,000,000 pounds per year, with a money value exceeding one and one-half million dollars.

Chemical and Physical Properties

The term alginates includes alginic acid and its salts. Chemically speaking, alginic acid is a polymer of a sugar acid, namely, d-mannuronic acid. As already indicated, sodium alginate is the most important of these compounds. However, alginic acid, ammonium alginate, calcium alginate and triethanolamine alginate are also available commercially for certain specific uses. Generally speaking, the alkali metal alginates are water-soluble, while those of the heavy metals are not.

Sodium alginate may be characterized as a hydrophylic colloidal polysaccharide. Algin has some properties similar to those of pectin and gelatin, and other properties recall the vegetable gums, but algin is physically and chemically distinct from all of these colloids. Algin should also be distinguished from agar and Irish moss (carragheen) which are also derived from marine plants but are chemically different from the alginate.

Sodium alginate is a white to light cream colored, amorphous, odorless and tasteless powder. It is soluble in both hot and cold water, but its solubility in water is limited by the viscosity of the resulting solution. The viscosity of sodium alginate solutions depends on a number of factors. The degree of polymerization attained and controlled during manufacture is an important consideration; highly polymerized sodium alginate is more reactive than the lower polymers. Viscosity is also affected by the concentration, the temperature and by foreign substances such as electrolytes and organic materials. An increased degree of polymerization in the alginate or a higher concentration of the compound markedly increases the viscosity. Increasing the temperature of an algin solution causes a decrease in the viscosity, but if the temperature does not exceed 50° C. this decrease is reversible. However, prolonged heating at high temperatures may cause permanent lowering of viscosity due to depolymerization of the algin. Storage at normal temperatures does not perceptibly alter the viscosity of properly preserved solutions.

Sodium alginate is compatible with a wide variety of substances. Water-soluble gums, proteins, soaps, starches, sugars, soluble oils, glycerine, sodium silicate solutions and many other materials blend readily with algin. Strong acids precipitate alginic acid from sodium alginate solutions. In solution, sodium alginate reacts with most metallic ions to give water-insoluble metallic salts. There are important exceptions, however, these being the alkali metal, ammonium, magnesium and ferrous ions, which form soluble alginate salts. The metallic alginates can be solubilized by addition of a strong ammonia solution, but when the ammonia evaporates the alginates revert to their insoluble form.

The reactivity of sodium alginate with metallic ions is an important considera-

tion in many of its applications and must be carefully controlled to avoid undesired thickening, precipitation or coagulation. On the other hand, careful addition of certain salts, particularly calcium salts, affords a convenient method for regulating the gelling of alginate solutions.

As with most natural colloidal materials, alginate solutions are subject to biological attack and decomposition. Hence a suitable preservative should be included in these preparations. Formalin, sodium benzoate, various substituted phenols, or the esters of para-hydroxybenzoic acid may be used. One producer reports good success with a combination of methyl para-hydroxybenzoate and butyl para-hydroxybenzoate in a ratio of 1 part of preservative to 2,000 parts of completed solution.

Aqueous solutions of sodium alginate are viscous, nearly colorless, odorless and tasteless. For many pharmaceutical and cosmetic purposes, solutions containing from two to four per cent of algin have been found convenient. To prepare the solutions, sodium alginate is added in a thin stream to either hot or cold water with constant stirring. If it is present or permissible in a formula, the use of glycerine facilitates solution and prevents lumping, the alginate being wet with the glycerine before adding to the water. When time is not a factor or when suitable turbulent-agitation equipment is not available, the algin may be sprinkled slowly into the water under manual agitation. After a few hours, the alginate will be dissolved. This procedure may also be used when other materials compatible with algin have been previously added to the water.

As was pointed out a few years ago, sodium alginate is very economical to use because by addition of the correct proportion of calcium ions in the form of a calcium salt like calcium citrate, mucilages of very low concentration may be prepared to have any desired viscosity and consistency. This reactivity enables algin to be used in any given concentration to form either thick true solutions, semi-mucilages similar to those made with tragacanth or karaya, or firia transparent gels or jellies comparable to products made with agar, gelatin or Irish moss.

Two recent patents are of interest in this connection. One of these patents describes how clear viscous solutions are produced directly from alkaline-earth alginates by adding compounds capable of sequestering the alkaline earth ions. Sodium hexametaphosphate, sodium tripolyphosphate and sodium citrate are used for this purpose. The patent also includes methods for preparing a glycerine hand jelly and an emulsion from calcium alginate. The second patent gives details on the formation of gels through the use of alginate mixtures. In these methods finely ground calcium alginate is mixed with a water-soluble alginate and added to water to form a stiff gel. By such procedures, maximum gel strength is obtained with 30 per cent calcium alginate and 70 per cent ammonium alginate.

Uses

Interest in the potentialities of sodium alginate in drugs and cosmetics probably began about a decade ago as a result of several reports on the methods and advantages of using this material. Recently the value of sodium alginate in pharmaceutical products was given recognition by its inclusion in the National Formulary VIII. The fact that the alginates are non-toxic is, of course, another factor in their favor.

Today, sodium alginate is widely used for thickening pharmaceuticals and cosmetics to give body to aqueous mixes. The ability of algin to form mucilages and gels of controllable consistency and density favors its use in hand jellies and

lotions, ointment bases, pomades and other hair preparations, greaseless creams, dentifrices and other products. Because of its high colloidal properties, sodium alginate serves as a satisfactory emulsifier and facilitates the blending of ingredients.

Cosmetics. As might be expected, sodium alginate has found frequent use in the formulation of hand preparations. The advantages of using sodium alginate in hand lotions, for example, stem from the fact that it increases the body of the mixture without requiring an increase in the solid content. It also acts as a stabilizer and is not sticky or waxy.

Alginates may also be used in the formulation of skin protective or "barrier" creams for the prevention of industrial dermatitis. Creams of this sort give flexible films with improved adhesion to the skin. The properties of sodium alginate likewise suggest its advantages for preparing various kinds of products for the hair.

It has long been known that sodium alginate is a useful ingredient of shaving preparations. In brushless shaving creams it acts as a stabilizer, makes the cream easier to spread and rinse from the razor, and lowers the solids content without affecting the action of the cream. It also imparts a definite gloss or finish to the cream. In the lather type shaving creams, the use of 0.2 per cent of sodium alginate prevents the cream from stiffening at high temperatures. Because the alginate increases the water-holding power of the cream, it stabilizes the lather, retards drying on the skin and reduces the bubble size.

By incorporating appropriate ingredients in sodium alginate solutions it is possible to prepare effective and pleasant after-shave lotions, liquid rouges and sun tan lotions. Algin is a useful ingredient of beauty masks or facial packs. When used in association with lime water, sodium alginate provides an excellent vehicle for paste products of this type. Quite interesting is the use of algin's foam-stabilizing property in the preparation of bubbling baths.

Dental Uses. Sodium alginate has found growing utilization in paste and liquid dentifrices. In toothpastes, algin acts as a suspending agent for the powder, is simpler to use than other gums, increases the wetting action of the paste, and will not corrode the tube. Calcium citrate may be used to thicken the mixture, but it has been said that dicalcium or tricalcium phosphates may cause trouble and should be avoided.

During recent years alginates have found valuable uses in dentistry as substitutes for tinfoil in processing acrylic dentures, as components of impression materials and as ingredients of denture adhesives. Of growing importance as impression materials, the alginates have the advantage that no heat is required for their preparation, and consequently there is no danger of burning the mouth of the dental patient. Improved technics for using these materials have been worked out, and various modifications of alginate impression materials have been developed.

Of pertinent interest is the use of alginates as hemostatics, or styptics. In a large number of cases of extraction and oral surgery, it has been found that powdered alginic acid applied to bleeding points combines with the calcium and immediately forms a coagulum that seals the wound. The styptic action is prompt, new tissue is formed rapidly and no untoward reactions were noted. More recently, sodium alginate has been combined with penicillin to make a styptic for dental work. In this method one gram of finely powdered algin is mixed with 0.1 gram of light magnesium oxide and autoclaved. On cooling, the sterilized powder is mixed with 20,000 units of penicillin. The resulting powder may be insufflated on to oozing surfaces to

produce an artificial "fibrin" clot and to check any possible sepsis.

Medicine. Of course, sodium alginate has found valuable applications in dermatology, but often the question of compatibility must be considered. Its solutions are particularly useful where consistency and good adhesion are factors incidental to therapeutic efficiency. Sodium alginate is compatible with such dermatologically useful agents as glycerine, the glycols, alkalies, phenol, tannic acid and boric acid, and with dilute (up to about 25 per cent) solutions of water-miscible alcohols. The solutions are compatible with some antiseptics, but not with others. They are useful media for application of sulfonamides.

Jellies made with algin have also been recommended for treating burns. One such preparation contains 5 per cent sulfanilamide, 20 per cent urea and phenyl mercuric nitrate in a ratio of 1 to 600. It is intended for packaging in tubes and is said to be analgesic, bacteriostatic and epithelially stimulating. The thickening and other properties of sodium alginate suggest its use also in lubricating jellies and related products.

Since it is used in making edible products, it is obvious that sodium alginate may also be used to prepare orally administered medicaments. It is useful, for instance, to prepare mineral oil emulsions, replacing the agar and tragacanth generally used for making these products.

Sodium alginate can effectively and economically replace tragacanth in the suspension of barium sulfate for radiographic purposes. Another field of utility for the alginates is in the production of pills and tablets. Alginic acid, which swells extensively in aqueous media, even in the presence of other salts and acids, is said to be a very suitable disintegrant for pills. For this purpose five per cent of alginic acid is incorporated in the mix and the tablets are made in the usual way. Studies have also shown that different proportions of sodium alginate had various effects on the granulation, sieving, compression and disintegration of tablets. Thus, one-half and two per cent of sodium alginate were highly effective with regard to disintegration of tablets, but the use of one per cent yielded poor results. In this connection it has also been noted that the film-forming characteristics of sodium alginate make it suitable for coating tablets.

Work is being done to further explore the potentialities of alginates in medicine and surgery. Recently, for example, experimental observations on absorbable alginate products were reported in which it was noted that alginates possess certain properties which make them attractive for surgical use. As clot, film, or gauze they are absorbed in animal tissue with minimal reaction. In addition, these products are readily sterilized by autoclaving.

Utilization Abstract

Origin of Corn Belt Maize. "The cylindrical-eared, yellow maize of the United States Corn Belt has frequently been said to have been handed down to the white man by his American Indian predecessors. Actually, this type of maize was unknown to the American Indian. . . . There is little doubt that Corn Belt maize came, in large part, from crosses between late, white, many-rowed Southern Dents, mostly of Mexican origin, and the early, long, slender, eight to ten-rowed Northern Flints which dominated eastern United States for centuries prior to the discovery of America". This viewpoint is supported by historical, archeological, genetic and cytological studies. (W. L. Brown, *Jour. N. Y. Bot. Gard. 51: 242. 1950*).

Citronella Oil

In 1948 almost 3,500,000 pounds of this oil were exported by Indonesia, Ceylon, Guatemala and Formosa. The United States is normally the principal consumer, finding many uses for it in perfuming soap, insect sprays, perfume formulas, menthol production, and for the manufacture of certain important synthetic organic chemicals. The Western Hemisphere has achieved a material degree of progress in its efforts at independence from distant sources of the Java type.

L. A. BARBER[1] AND M. D. HALL[1]

Introduction

Citronella oil is an essential oil, and essential oils are obtained principally by distillation from botanicals. Sources of raw materials are various parts of citrus fruits, trees, shrubs, grasses and other plants. Citrus fruit peels are mostly expressed (cold pressed), but small quantities are distilled. Some flowers are distilled by steam, some are processed by volatile solvents, while others are treated by enfleurage. Additionally, essential oils evaporate at ordinary room temperature and are valued for their employment in perfume and flavor formulas. Toilet preparations, soap, food products (baking, confectionery and beverages), disinfectants, inks, shoe blacking and almost every other item which is perfumed or flavored owe their appeal in whole or in part to essential oils. Since they appear in many products for the sole purpose of masking unpleasant pharmaceutical and industrial odors and tastes, the layman is often unaware of their presence. Essential oils differ from fixed oils, e.g., castor, olive and peanut, in that the latter do not evaporate at room temperature, are more viscous, have oily characteristics and are all obtained by cold pressing.

When one considers that United States imports of all kinds of essential oils from all parts of the world in 1948 amounted to 6,549,460 pounds and that 1,713,033 pounds of citronella alone were included in that figure, one can understand why citronella oil is important to United States manufacturers and to the national economy of the exporting countries.

Citronella oil is not commercially produced in the United States. Experimental cultivation, however, has been conducted in Florida and Puerto Rico, but this country is dependent upon imports for its requirements, nine countries having contributed to our stocks during the first nine months of 1949.

Botany and History

Citronella is the most important, especially in terms of world output, among several essential oils produced by various strongly scented members of the grass family. References to it under various names (2) are contained in Sanskrit writings, in the Old Testament and in other documents of antiquity. The first mention by European writers is to be found in the works of Garcia da Orta in 1563; of van Rheede tot Draaken-

[1] Economic analyst and research analyst, respectively, in U. S. Department of Commerce, Washington, D. C.

stein, 1678–1703; and of G. E. Rumpf, 1741–1755 (2). Because of their fragrance citronella and other aromatic grasses have been used since antiquity in the preparation of oils and ointments and in the aromatization of wines; and as incense in religious rites (3, 4).

Citronella and its close relative, lemongrass, belong to the genus *Cymbopogon* which very closely resembles and formerly was included in the genus *Andropogon*. The terms "citronella" and "lemongrass" have at times been confounded, and their respective oils have not always been properly distinguished, with the result that confusion has occurred in the literature regarding the two. Citronella grass is known in several varieties, and the parent of them all is probably the mana grass of Ceylon which, according to Finnemore (5), occurs today in two wild forms, *Cymbopogon Nardus* var. *Linnaei* (*typicus*) and *C. Nardus* var. *confertiflorus*. The oil of these wild forms is not known to be distilled to any appreciable extent, but it may possibly be mixed with what is known as the Ceylon type of that which is distilled. This leads us to note that there are two types of commercially cultivated citronella grass, the Java type, technically referred to as *Cymbopogon Nardus* Rendle var. maha pengiri (or pangiri) (= *Andropogon Nardus* L.), and the Ceylon type, known as *C. Nardus* Rendle var. lena batu (= *Andropogon Nardus* Ceylon, de Jong). Each type has its special merits and applications.

Although much has been written in standard references, trade journals and scientific papers by individual researchers, standards were first collectively established in the United States by the Scientific Section of the Essential Oil Association of U.S.A. (1) in their E.O.A. No. 14 for the Java type of citronella oil, and in their E.O.A. No. 12 for the Ceylon type.

Citronella Java

Culture. The Dutch introduced citronella into Java from plants obtained in Ceylon. Both the so-called Java and Ceylon types were experimented with, and the Java type was ultimately selected for estate commercial propagation.

The Java type plants (*Cymbopogon Nardus*, maha pengiri) require good soil and much care, since they are surface feeders of rapid growth, occurring in large tufts with broad leaves, and take a great deal out of the earth.

Altitude, climate and soil conditions profoundly affect the vitality and life span of the plants as well as the yield and quality of oil, particularly its citronellal content. Rich alluvial soil at an altitude of about 600 feet in a humid climate probably offers the most favorable conditions for good yield and quality of oil, and also guarantees sufficient longevity of the plantings. Although it does grow at lower altitudes, the grass develops there very slowly during the dry season, with the danger of dying if cut at the beginning of or during that period. Careful drainage of soil is a necessity, since too much water makes the leaves grow quickly, and formation of oil suffers.

In Java new plantings are made on deforested burned-over areas during December to February, which is the first part of the rainy season. This is the proper time, since the grass requires a fairly large amount of moisture.

The planting material is obtained by dividing well-grown clumps, for it is difficult to grow the grass from seed. About ten stalks are obtained from each clump. The stalks are planted in holes about three feet from each other. Weeding, hoeing and hilling are required.

Finnemore (5) said it was the practice to make the first cutting after five or six months and thereafter every four months. Guenther (6) in 1942, as a

result of actual field visits, stated that cuttings should be made every three months, beginning the second year, since new plants yield nothing the first eight or nine months. Both authorities are agreed that replanting should take place after four years because of soil exhaustion. On well-cared-for lands plants can be continued until eight years old or longer, but after four years the quantity of grass and oil diminishes very materially. During 1934–42 estates furnished one-third of the oil in Java, while native plantings, two to three years old, accounted for two-thirds of the grass harvested (6). An analysis of Government statistics in 1942 showed that only 20 percent of the grass was grown on large estates.

FIG. 1. Java type of citronella grass.

Because of the cost of imported fertilizers and the fact that oil yields were subnormal, it was more economical for estates to utilize new terrain for replanting. Fallow ground was planted to special bushes which threw off large amounts of leaves, rejuvenating the earth. Individual natives, however, cannot afford to hold any land not in use, and replanting is done on the same terrain. The lure of ready cash entices many small native growers to harvest more than three times a year at improper times, thus injuring their plants and lowering their longevity. Certain essential oils in other countries are similarly distilled out of season, when the date of maturity has passed and the quantity and quality of the oil are lessened. The reason is that the distillers are farmers whose primary crops are foodstuffs, ripening during the same period as the oil-bearing material, and the essential oil naturally is given secondary consideration.

From the foregoing it will be appreciated that it is difficult to estimate the yield of grass and oil per acre. However, Finnemore (5) did state in 1926

that the yield then was from 50 to 60 pounds of oil per acre, which is comparable to Guenther's (6) statement of an average of 56 pounds per acre in his analysis of 1942.

Cultivation is centered chiefly in West Java, especially in Priangan. The estates are located principally in Java and Madura, although seven percent are situated in the Outer Islands. Areas under cultivation in Java for specified years were: 1923, 15,000 acres, divided among 30 estates (5); 1933 and 1934, about 66,700 acres (⅓ estates, ⅔ native) (7); 1935, 45,000 acres (⅓ estates and ⅔ native) (6); 1937, 59,304 acres (27,000 hectares)[2]; 1948, 12,000 acres (8)[3]. Hischmann (9) calculated that 607,200,000 pounds (276,000,000 kilograms) of grass were required to distill the oil produced in Java in 1935, or approximately 3⅓ million pounds of citronella oil, Java, at 0.6 percent.

Distillation. The estates distill the grass in their own distilleries, of which there were almost 100 in 1937, some 12 of them also buying the grass from native growers. In that year 80 small native distilleries were said to be in operation, all in Priangan (6). In the Preanger area native plantings accounted for a considerable volume in 1934, the grass being distilled by some 75 native factories with a production of about 255 metric tons of citronella oil (7).

The grass is cut in the early morning and dried for three to four hours; it must be turned over several times to prevent fermentation. Three types of stills are employed in Java: with water and steam; a modified form of water and steam; and direct steam distillation.

The first method is in general use by the natives because it is simple and the least costly to install and operate. Water is heated under a grid upon which the grass is placed. The resultant steam-oil is conducted off and condensed, the oil separating on top of the water. A separate fire is required for each still, making for a greater fuel consumption than for steam where one boiler can service a number of stills at one time. The duration of distilling by water and steam is three to four hours.

The modified method of water and steam distillation is usually employed by wealthy natives and Chinese. The hearth and the water boiler are separated from the actual still, obviating injury to the grass which sometimes occurs with direct fire distillation. The most suitable charge for this type of still is from 1,000 to 1,200 kilograms of grass, while the most favorable duration is from three to four hours.

Steam distillation has been employed by the large estates from the beginning of the industry. Steam is generated in a separate boiler which can service a battery of stills. Wood or exhausted grass is utilized. In 1942 direct steam stills held charges of 1,000 to 1,200 kilograms of grass under atmosphere pressure of one-half to one throughout a distillation period of three hours.

Java type oil contains a higher percentage of citronellal and total geraniol than the Ceylon type. To this fact is ascribed the finer odor of the Java type. As will be shown later, a wider variety of derivatives is obtained, which means that the Java type can, in cases of necessity or desire, be used to replace the Ceylon type—but the Ceylon type cannot economically replace the Java as basic material for some of the derived synthetic organic chemicals.

The constituents distill over in the following order: various low-boiling terpenes; citronellal; a mixture of citronellal, geraniol and various esters; geraniol; and sesquiterpenes and sesquiterpene alcohols.

The aforementioned cultivation fac-

[2] 1 hectare = 2.471 acres.

[3] It is possible that this estimate comprises only estate acreage. The unsettled political conditions do not permit verification.

tors and one or more of the processes of distillation apply equally to the production of citronella oil, Java type, in all parts of the world. As stated previously, all countries commercially producing citronella oil grow and distill the Java type, with the sole exception of Ceylon which now furnishes only the Ceylon type. However, it is said that some Java type oil is produced on Ceylon estates but is mixed with the Ceylon type. Singularly enough, both types originated in Ceylon.

Citronella Ceylon

Culture. *Cymbopogon Nardus* Rendle. var. lena batu, is the source of the Ceylon type of citronella oil. As noted in the preceding paragraph, a minor quantity of oil distilled on the Ceylon plantations is from the Java type grass and is mixed with the Ceylon type instead of being sold separately (10), the reason being that foreign buyers are unwilling to pay a higher price than for the regular Ceylon type. If purchasers want the better quality, they can obtain Government guaranteed oil from Java.

The lena batu type, or new citronella grass, originated about 1885 near Matara in southern Ceylon, possibly as a hybrid between mana and old citronella grass (maha pengiri). Owing to its hardy nature, possibly due to its probable hybrid origin, it almost replaced the older grass (5).

It is a deep feeder and flourishes on poor soil, generally on hillsides. Cultivation is confined to the south, the Galle district being the first important cultivated region. Later Galle was superseded by the Matara district, extending to Tangalla and parts of the Hambantola district (5).

Like the Java type it grows in tufts but has narrow leaves and does not require much care or moisture. It is propagated by dividing the tufts of old plants and replanting them. The first crop can be harvested eight months after planting and every three months thereafter. Plants can be harvested for 15 years, but after the tenth year they should be replaced. Weeding should be done at least annually, and the soil should be fertilized with the ashes of the distilled grass after it has been used as distillation fuel.

In 1940 some 30,000 acres were under cultivation compared with 40,000 acres in 1911. All cultivation is owned by Singhalese whose holdings range from half-acre plots to plantations of 300 or more acres. Prior to planting new tracts the ground is burned over and hoed. The interval between plants is one and one-half feet, planting time being from May to August and November to January. Harvesting takes place from March to April, June to July, and November to January 15.

Both Finnemore (5) and Guenther (6) state that the average output of grass per acre is eight tons, yielding 0.4 percent of oil, or 70 pounds per acre. The third year gives the maximum yield of 80 pounds per acre, while the output is only 40 pounds per acre from plants five to ten years old (6).

Distillation. The stills in Ceylon are reportedly very efficient and relatively modern. They are serviced in pairs by a separate steam-generating boiler which furnishes steam to one while the other is being emptied of spent grass and refilled. One condenser suffices for both stills. The distilled oil is collected in a locked container which prevents pilferage. Small distillers of sugar cane use the same protective measures in the West Indies. Guenther (6) states that the charge for the standard size still is one-half ton, distillation time being six hours. Finnemore (5) records charges of from 700 to 2,000 pounds, six hours distillation duration and two charges per day.

FIG. 2 (*Upper*). Harvesting citronella grass in Java.
FIG. 3 (*Lower*). Harvesting citronella grass in Ceylon.

Specifications

The Scientific Section of the Essential Oil Association of U.S.A. (1) in E.O.A. "Standard for Citronella Oil—Java Type, E.O.A. No. 14", states that it is the "volatile oil obtained from the cultivated grasses botanically classified as *Cymbopogon Nardus* (Rendle) or *Andropogon Nardus* (L.), family Gramineae, variety, maha pengiri, obtained by direct steam distillation of the freshly cut or partially dried grass. It is characterized by a light yellow to tan color, low viscosity and pronounced aldehydic odor". The following specifications are listed: "Specific gravity at 15° C., 0.883 to 0.900; optical rotation, −0° 30′ to −6°; refractive index at 20° C., 1.4660 to 1.4745; total aldehydes as citronellal, 30 percent to 45 percent; total alcohols as geraniol, 85 percent to 97 percent; and solubility—clearly soluble at all dilutions between one and two volumes of 80 percent alcohol and may become opalescent on further dilution"[4]. Assay methods and other information are included in the reference.

E.O.A. No. 12 of the Association describes its "Standard for: Oil Citronella Ceylon" as the volatile oil from *Cymbopogon Nardus* Rendle, lena batu or *Andropogon Nardus* Ceylon, de Jong, obtained by direct distillation of the dried grass. It is a yellow to yellowish brown liquid with the following physical constants: Specific gravity at 15° C., 0.898 to 0.910; optical rotation, −9° to −18°; refractive index at 20° C., 1.4790 to 1.4850; clearly soluble at some dilution between one and two volumes of 80 percent alcohol. When diluted to ten volumes the solution should remain clear or become not more than slightly opalescent with no separation of oil after standing overnight; test for mineral oil (saturated hydrocarbons), negative; aldehyde content, seven percent to 15 percent, calculated as citronellal; and total alcohols, calculated as geraniol, 55 percent to 65 percent. Assay methods and other descriptive characteristics are included.

Other constituents, while considered of minor importance, influence the odor of these two types of oil. Among others found in the Java type are citronellol, detected by Flatau and Labbe (17, 18); iso-valeric aldehyde and iso-amyl alcohol, said to be present (11); and methyl eugenol, less than one percent (5).

The Ceylon type upon analysis has been shown to contain: *l*-borneol, one to two percent, first isolated by Schimmel & Co. (16); camphene, identified by Schimmel & Co. (15); camphene, isolated in solid form, melting point 49–50° C. (13); dipentine (tetrabromide, melting point 124°) (14); limonene (19); farnesol, pure and as esters in proportion of 0.2 to 0.3 percent, found by Elze (12); methyl heptenone, first detected by Schimmel (18); and methyl eugenol, seven to ten percent; nerol present in small quantities and *d*-citronellol present in the form of the acetate and butyrate (5).

Economic Status

The national economy of the United States is composed of a great number of industries which are fed by domestic and foreign suppliers of raw materials and intermediately processed products. The predominant position of the United States has been achieved by applying accrued technical knowledge to its production problems, thus increasing production at lower costs, and to the distribution of this mass production by the most highly developed sales methods,

[4] "Total geraniol or alcohol content" is a collective term for all the constituents which can be esterified with acetic anhydride. Not only citronellal and geraniol, but other compounds like citronellol, citronellol esters, geraniol esters and sesquiterpene alcohols, fall into this group.

FIG. 4 (*Upper*). A native distillery in Java.
FIG. 5 (*Lower*). A native distillery in Ceylon.

domestically and internationally. Price and quality have been the foundation of this success, the combination placing American merchandise not only in a competitive position, but very often ahead of foreign competitors.

The United States is not a producer of citronella oil, and its purchases of the oil from foreign sources are made on the basis of high quality and competitive price. From the following analysis of citronella oil-producing countries it is interesting to note that Java succeeded in establishing a very worthwhile industry because it perceived superior odor and application principles in the Java type, while Ceylon, the cradle of both the Ceylon and Java types, went on to produce the Ceylon type for a lower sales price and permitted adulteration in its product.

It is true, however, that the soil of Java is better suited for the Java type than that of Ceylon, but the Dutch were willing to give more attention to cultivation and obtain smaller total quantities of oil per acre in order to produce a superior quality, for which they have obtained, with few exceptions, higher per pound selling prices.

It is also significant that seven of the eight countries which cleared shipments into the United States during the first nine months of 1949, produced only the Java type, the eighth country being Ceylon which shipped the Ceylon type.

Future imports of citronella oil into the United States are not easy to forecast. So much depends upon the speed and continuation of rehabilitating the Javanese areas; how much synthetic menthol will be processed from Java type oil which now finds itself in competition with natural menthol from Japan and Brazil; and what quantities of other synthetic organic chemicals will be manufactured from the oil. Then again, one cannot estimate the potential purchases of European manufacturing countries which will draw supplies from the same sources as we do.

Nevertheless, Table I shows that probable United States imports should be between two and three million pounds

TABLE I

IMPORTS IN POUNDS OF CITRONELLA OIL INTO THE UNITED STATES, 1935-49[5]

(Bureau of the Census, U. S. Department of Commerce)

Year	Total Imports	Indonesia	Ceylon	Guatemala
1935	1,682,574	886,523	695,251	25,032
1936	1,584,773	1,008,847	515,304	30,992
1937	1,600,951	712,125	831,776	57,050
1938	2,099,840	1,156,093	766,470	87,154
1939	2,744,140	1,942,260	636,015	165,865
1940	2,902,685	2,369,312	388,218	145,055
1941	4,266,675	3,973,662	171,619	107,125
1942	1,422,637	903,687	495,174	21,060
1943	354,994	1,227	236,498	111,178
1944	963,120	2,314	177,628	259,577
1945	691,506	None	483,409	158,936
1946	829,665	85,888	287,402	315,756
1947	1,340,762	401,880	526,750	251,095
1948	1,713,033	555,001	353,069	648,472
1949	1,324,863	147,675	247,276	538,625

[5]First nine months of 1949.

annually. The Table shows total imports for 1935 to 1949, as well as shipments from the three most important future suppliers, Indonesia, Ceylon and Guatemala.

Table I shows that imports for 1947–49 were approximately of the same volume as for 1935–37. This might be construed as our current requirements. However, the period 1938–40 probably reflects our actual requirements more closely. Larger volumes of soap and toilet preparations have consistently been manufactured since World War I, and citronella oil and its derivatives are employed in large quantities in both, especially the Ceylon type in soap perfuming. The abnormal receipts from Indonesia during 1941 are undoubtedly accounted for by removal of ready stocks to prevent their seizure by the Japanese. The recent war years tell their own story. Lack of shipping facilities was a factor in Ceylon's picture, although price may have been a contributing cause, since imports of two different odor types of South American essential oils used in soap showed very marked increases.

Producing Regions

Since there are too many supplying countries for discussion under each economic heading, we shall treat each country individually.

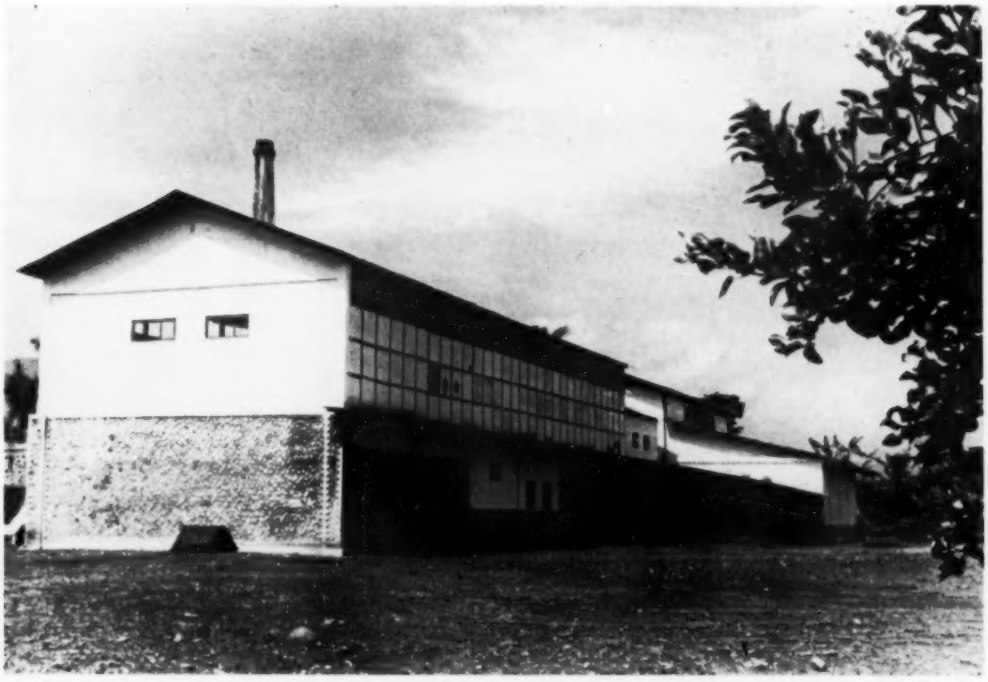

FIG. 6. A modern distillery in Java.

Java. Accepting the official statistics of planted area in 1933 and 1934 as 660,700 acres (⅓ estates, ⅔ native) (7), it is obvious that the Indonesian economy was dealt a severe blow, when estimates for 1948 were only 12,000 acres (8). Additionally, only 881,600 pounds of oil were produced in 1948 because of the neglect of the fields and for other reasons. This accounts for the small exports to the United States in 1948 and 1949.

The Java type oil is used to scent

soaps, disinfectants and shoe polishes, and enters into a great many perfume formulas used in a multitude of preparations, both aesthetic and technical. As a raw material it is employed to manufacture geraniol and citronellal, the citronellal content being further converted into hydroxycitronellal, *l*-menthol, geranyl acetate and citronellol. It is stated that from six to seven pounds of Java type oil yield one pound of U.S.P. menthol and one pound of non-U.S.P. menthol.

From January 1, 1938, all export shipments were subjected to test and certification by the Analytical Laboratory at Buitenzorg, Java. Inspections by this laboratory were resumed October 1, 1948. The Association of Citronella Oil Producers in Java was very alert to the advantage of maintaining high quality output.

The Dutch reasoning has been logical. They developed a better oil type than Ceylon, the better type could be converted to a wider number of uses and they obtained higher prices therefor; hence the incentive and financial ability to expand production, all topped by official export analysis and certification. These reasons account for the fact that all new producing countries are cultivating the Java type, their plantings having become established while Java was out of the world market because of occupation by the Japanese.

From price fluctuations of recent years it is apparent that citronella oil is currently a highly speculative commodity, and it is not contemplated that prices will be stabilized until production is increased in Java and political and economic conditions become more normal. This Javanese disruption and high prices enable the infant citronella oil industries in the other producing countries, especially in the American Republics, to get established while prices are good and while the original and largest producer, Java, is unable to regain its world markets, particularly that of the United States.

Ceylon. Large quantities of the Ceylon type are used by soap manufacturers. It is also employed in shoe polish, fly sprays and many industrial preparations.

Two types are offered by exporters, *viz.*, Estate quality and Schimmel Test (fair average quality, or F.A.Q.). The presence of kerosene or other hydrocarbons used as adulterants in the second type has not helped Ceylon any.

Midyear is ordinarily a time when demand is good. In 1948 sales were not moving too well, the reason being given that new chemical compounds were claiming a good part of the market for mosquito repellents. Dimethyl phthalate, derived from phthalic anhydride, is said to have been the best repellent of all types of insects used by the U. S. Army (20).

The citronella oil industry in Ceylon is reportedly in a state of decline. Part of the remedy, according to some authorities, lies in abolishing the practice of adulteration. If Government control were imposed on all exports so that export permits would be granted only on shipments passing a quality test by a qualified analytical laboratory, it is believed that the situation would be improved. Today there is no such trade or government check. The exporters make their sales on the basis of Estate or F.A.Q. types.

Guatemala. A glance at Table I shows that Guatemala made excellent progress during the years 1935–41 in establishing itself in the United States market. It had to overcome many obstacles, and the year 1942 augured ill for the infant industry. It recovered, however, to furnish more than either Indonesia or Ceylon in 1944, 1946 and 1948, and led both

these countries during the first nine months of 1949.

This achievement was not accidental. It was planned on the foundation of high quality and fair price, the same factors which created Indonesian stability and expansion.

That Guatemala intends to retain its position is evident from a report in August, 1949, that their "Development of Production" (INFOP), which was then only six months old, had granted

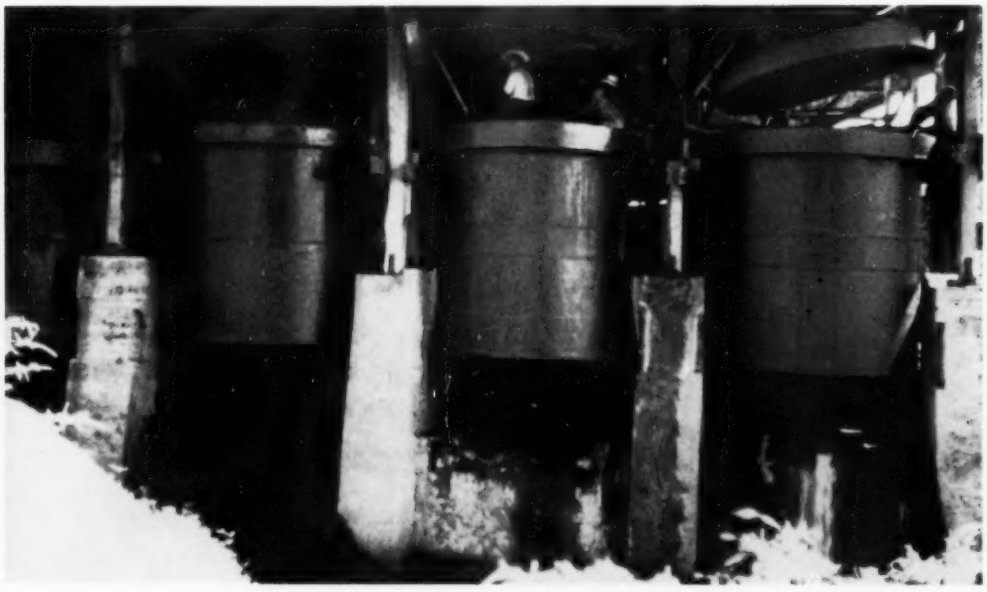

FIG. 7. Distilleries in Guatemala.

credits of $482,059 for agricultural working capital of citronella, corn, coffee, bananas and other crops. Of this amount, $346,500 was allocated to citronella.

Export quotations and shipments are made only by the Control Office of Essential Oils, which warehouses all production, analyzes and grades the oil, and sells in foreign countries only through its own resident agents. This association has quasi-government status, being able to enforce its administrative and other regulations through a Presidential Decree. It is comprised of about 46 distillers and anticipates an output of 1,000,000 pounds of citronella oil, Java type, in 1950.

The U. S. Agricultural Attaché in Guatemala reported in 1947 that he was receiving a surprisingly large number of inquiries as to sources of planting stock. Some foresighted individuals have planted fields for the sole purpose of selling such plants at attractive prices.

The National School of Agriculture in Guatemala presented a short practical course for small farmers. The Ministry of Agriculture and the Guatemalan Agricultural Research Station cooperated.

It is stated that exhausted citronella grass (after distillation) cannot be mixed with molasses and fed to cattle because they will not eat it. One large distiller contemplated manufacturing fiber board and later paper from this residue, instead of using it for fuel.

The citronella farms of Guatemala are almost entirely grouped in two localities.

The older and larger group is in the Department of Escuintla. The other group is located in Retalhuleu, about 100 miles to the northwest. Although these farms are near the Pacific coast, shipments of oil are made through Puerto Barrios on the Atlantic coast (21).

Guatemala is said to possess one of the most modern stills in operation.

Honduras. The industry in Honduras appears to be passing through the same labors experienced by Guatemala. Exportation of citronella oil, Java type, from July 1, 1945, through June 30, 1946, was reported at 117,639 pounds, placing this commodity sixth among Honduran exports originating from agriculture.

The Tela Railroad Company reported that at the end of 1946 it had 784 acres cultivated experimentally in citronella grass. The present known total planting in Honduras is 457 acres, the Tela Railroad Company accounting for 342 acres. The decline in price and the cost of providing new stills did not warrant larger scale development, according to the railroad. However, for small farmers it is still regarded as a profitable undertaking.

During the first nine months of 1949 the United States imported 42,046 pounds of citronella oil from Honduras.

That expansion will occur is evidenced from the fact that 15 acres have been used to obtain seeds or plantings for an additional 200 acres next year. Again, a report received in December, 1947, stated that an American planted 86 acres of citronella grass in the vicinity of Quininistan, near the Guatemalan border, and expected to begin distillation in January, 1948. With a still then being built he expected to obtain from 100 to 125 pounds of oil daily. In January, 1948, he contemplated planting an additional 100 acres and eventually another still.

Formosa (Taiwan). The Java type grass is grown on small plantations started by the Japanese in 1939, at which time the island was still a part of the Japanese Empire. The output was intended for domestic consumption in Japan to make them independent of Indonesian suppliers. Surplus quantities were to be offered in international trade. Total output in 1948 was estimated at 200,000 pounds, and 1949 production was said to be increasing.

Cultivation is located along the northwestern coast near Tahu, Mori and Tai Chu. Formosa was a commercial exporter in 1939, the first year of citronella oil production. The U. S. imports of 13,888 pounds from Japan in 1941 were undoubtedly of Formosan origin, since Japan proper is not known to have been a producer.

Upon the return of Formosa to China after World War II, exports were resumed. None of this oil was shipped direct to the United States during 1948, but 51,874 pounds were directed to this country through Shanghai. China is not a producer. Direct shipments from Taiwan to the United States during the first nine months of 1949 totalled 41,200 pounds, while receipts during the same period via China amounted to 301,347 pounds.

While the countries already discussed constitute the actual world suppliers of more than 90 percent of this commodity, it must not be forgotten that, apart from Ceylon and Indonesia, the advent of citronella cultivation in the other countries is only of recent occurrence.

Similarly it must be borne in mind that other Western Hemisphere countries are either producing limited quantities of the Java type oil or are experimenting with citronella cultivation. Remembering that the small seed of today may be the germination of the large plantation of tomorrow, we shall list some of these potential sources.

Haiti. Experimental cultivation was

commenced during the recent war years by SHADDA, a United States Government Agency. The project has been discontinued. No oil was commercially produced. Then local planting was made by a European trained Haitian agricultural engineer. He is already shipping seven essential oils to the United States, and while the quantities are still small, they are progressively increasing. The prospects are considered excellent. United States receipts of citronella (Java type) were 626 pounds (1945), 1,305 pounds (1946), and 3,087 pounds in the first nine months of 1949.

Dominican Republic. In August, 1941, the Brookings Institute obtained complete commercial information from the United States Department of Commerce on the subject, and as a result of the survey it recommended that a citronella cultivation project be established for the European refugees in the Dominican Republic. The following poundage of Java type oil has since been received by the United States: 440 (1944), 985 (1945), 1,305 (1946), 3,190 in the first nine months of 1949.

Leeward Islands. Receipts of 417 pounds by the United States in the first nine months of 1949.

Brazil. Citronella oil is reportedly available from the State of Espirito Santo.

El Salvador. United States imports have been: 297 pounds (1942), 105 pounds (1943), 125 pounds (1944), 122 pounds (1945), 94 pounds (1946), and none during the first nine months of 1949. This was only for experimental purposes and was of the Java type.

Philippine Republic. The Bureau of Plant Industry increased the planting of citronella grass in 1941 and planned to install a new still. There is no postwar information on the project.

Nicaragua. A small experimental plot was planted in 1944 at the Nicaraguan Government Nursery at Masetepe and at the United States–Nicaraguan complementary crop experiment station near El Recreo. Propagation clumps were to be made available to interested persons. No subsequent information is at hand.

Mexico, British Malaya, India. These have been listed within the last ten years as shippers of small quantities to the United States. While other countries have also appeared in the statistics; it is evident that they were merely transshippers.

Current data and special articles appear periodically in such trade journals as The American Perfumer and Essential Oil Review, Soap and Sanitary Chemicals, and Drug and Cosmetic Industry.

Conclusion

From a small start in 1885 in Ceylon was born a commodity which today is in such demand that new countries are struggling for their share of the commerce. The majority of these countries are Western Hemisphere Republics. Price and quality will determine the outcome, but the New World appears able to compete with the older sources in these respects. New uses may be discovered, and the known derivatives may be further processed or combined to open up new fields, which will require further quantities of this oil, just as vitamin A was recently synthesized and is now manufactured from beta-ionone derived from lemongrass oil, a very close relative of citronella, since it is obtained from another species of the same genus, namely, *Cymbopogon citratus* (D.C.) Stapf.

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Utilization Abstract

Cork Substitutes. The cork oak, *Quercus suber*, of Portugal, Spain and neighboring lands of the western Mediterranean area, has always been the world's principal source of cork, but shortage of that supply during the last great war stimulated a search for substitutes. The best found so far is Brazil's pau santo (*Kielmeyera coriacea*) which " has been used in Brazil for some 30 years as a cork substitute. It is described as the closest to natural cork of any materials examined in the world-wide search during World War II. The pau santo or ' holy wood ' grows by the millions in the Brazilian States of Minas Gerais, Sao Paulo, Goias and elsewhere. The cork-like bark can be easily stripped off with an ordinary facao de mato or jungle machete, and small quantities now reach the market ".

" Experiments with these small amounts have found that the pressed bark makes excellent corkboard pipes, insulation walls, and practically every other article for which cork normally serves. ' Cork ' from pau santo has, in fact, been tested and found to be suitable for life-savers, boat bumpers, mooring buoys, floats and bobbers, industrial gaskets and seals, glass and china polishwheels, sporting goods, shoe lifts, cigarette tips, novelties, corkboard, corkpipe, corksheets, jar-cap liners, insoles and other purposes ".

" During the last war, when cork was extremely scarce and the flow of imports from the Mediterranean countries which mainly supply it was sharply curtailed, several United States firms experimented with pau santo. They found that it was from 85 to 95 percent as good for basic purposes as cork ", that is, for grinding into composition-making powder, for which purpose more than 60% of the U. S. cork imports are used.

Three advantages are claimed for pau santo over the cork oak of Mediterranean lands: it can be stripped from ten-year-old trees, whereas cork oaks are not " ripe " for 20 years or more; a pau santo tree will yield a second crop after five years or less, whereas the cork oak requires at least ten years; and the best quality oak cork will usually be found only on trees that have been standing for at least 40 years, while pau santo trees produce a good grade within 12 years.

Collection of pau santo cork is still an unorganized industry of individual farmers, and the problem of getting large quantities of the material to market is a real one. A report in 1941 by the U. S. Embassy at Rio had the following to say about the material, however:

" Brazil may prove a valuable source of raw material for the American cork industry. A firm in Sao Paulo is making an insulating material from pau santo bark, which, in weight and appearance, resembles corkboard. Estimates vary as to the amount of this raw material which could be assembled for export, but the latest report states that ' exportable quantities of the bark would be available to the extent of some millions of tons, depending on demand and prices. At present this bark is purchased by only two cork factories in Brazil to the extent of about 4,000 tons each annually. Larger purchases of this bark in the interior would have to be financed and organized by another company as present operators are not prepared to invest additional capital ". (Anon., *Brazilian Bulletin 7(162): 7. 1950*).

Leucaena—*A Promising Soil-Erosion-Control Plant*

This woody legume, originally native to Mexico but now naturalized in Arizona, Florida and Texas, has been extensively used in Indonesia for soil erosion control and should be similarly employed in our Southern States.

M. J. DIJKMAN[1]
University of Miami, Coral Gables, Florida

Introduction

In discussing measures of inexpensive large scale erosion control in tropical and semi-tropical regions in general and especially in connection with our southern States, the writer explained to the well known authorities on economic plants, Dr. David Fairchild and Dr. Walter T. Swingle, of the results obtained with *Leucaena glauca* in Indonesia and Hawaii. In response to their suggestions, the experience obtained with this legume will be discussed in the following pages. It seems strange that this plant, which has gone wild in all the States around the Gulf of Mexico and in the islands of the Caribbean Sea, is not yet utilized for this purpose in America.

The writer will confine himself in this paper mainly to *Leucaena glauca* (L.) Bentham, for this species is best known and its uses are best worked out. Moreover, it is the cheapest leucaena of the three planted in the Pacific and now in use there in forestry, agriculture, dairy farming and beef cattle raising. It may be stated, however, that the study of two other species of this genus, *L. pulverulenta* (Schlecht) Benth. and *L. glabrata* Rose, and their hybrids with *L. glauca* have become most important subjects of research on account of their tremendous value as aid-plants for perennial crops and forestry in Indonesia.

[1] Former agronomist of the Association of Central Experiment Stations and head of the Extension Service for plantation crops of the South and West Sumatra Syndicate in Indonesia.

Origin and History

L. glauca is an arborescent legume belonging to the Mimosaceae. Its original habitat is Mexico where it first was found from Jalisco to Michoacan in Chiapas and Yucatan (66).

The exact date of its importation into the Pacific is unknown, but it was probably linked with the Spanish occupation of the Philippines and Indonesia. The peoples of the Pacific plant *L. glauca* for its young leaves and its seeds, both unripe and dry, which are eaten as a side dish with rice along with coconut, fish and meat (3, 25, 46, 66, 67).

The first account of its agricultural importance is found in the coffee literature from Java, early in 1900, where *L. glauca* is mentioned in connection with the shading and fertility maintenance of the soil (3, 8, 29, 49).

Botanical descriptions of the legume in its original Mexican habitat and that of the plant as it is found on the various islands in the Pacific show discrepancies in the length of the leaves; number and length of the pinnae, flowers, pods; seeds per pod and relative size of the trees

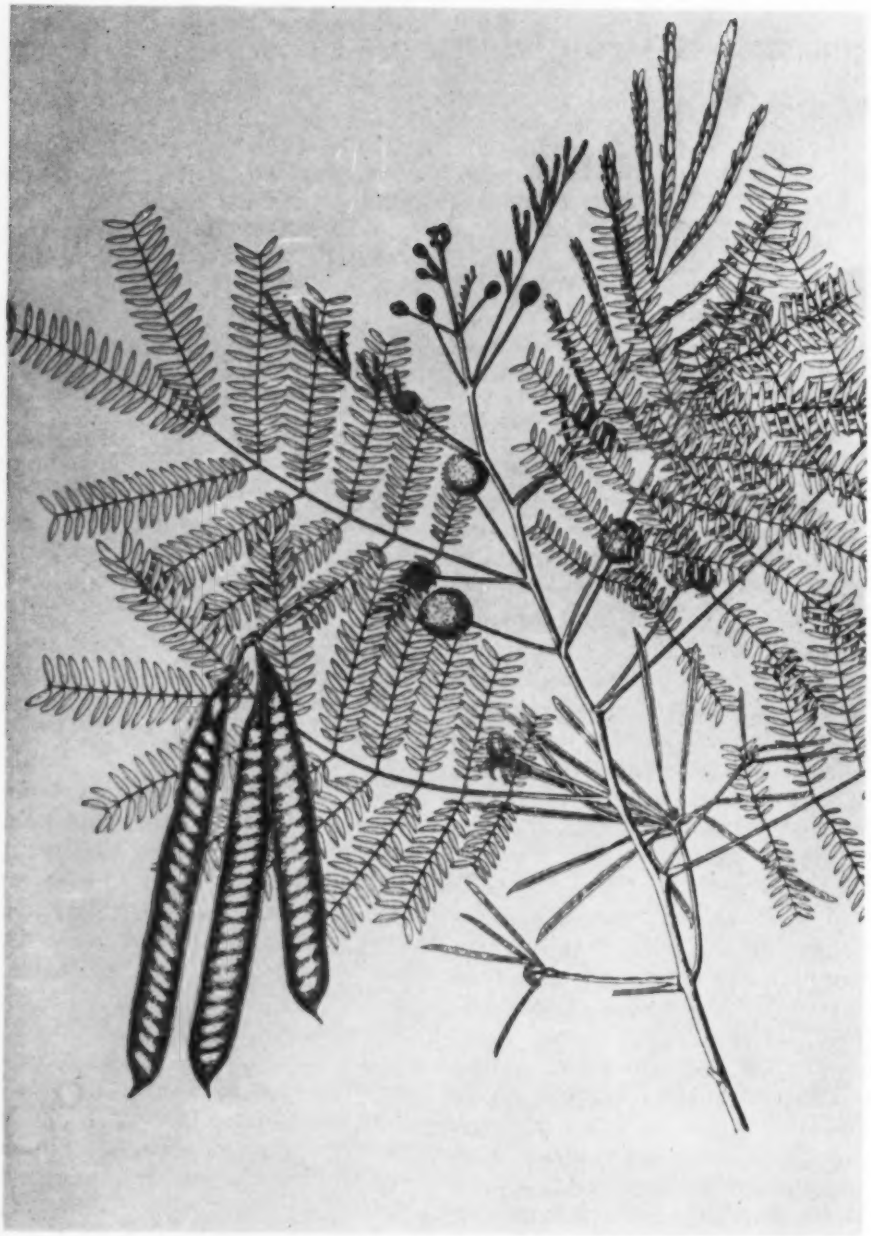

FIG. 1. *Leucaena glauca* (L.) Benth. (After C. A. A. Backer and D. F. van Slooten, 1924.)

(3, 66, 67), which makes a wide comparative study of local types in their new, acquired habitats desirable. The fact that the former Netherlands Indies Forestry Service segregated out a giant type known under the Indonesians as "lanang", which term means "male" in the sense of its growth-vigour and physical appearance (18); the discovery that the species *L. pulverulenta*, when planted mixed with *L. glauca* under natural conditions, produces up to 25% hybrids (35); and the fact that the Hawaii Agricultural Experiment Station found appreciable variation in the amount of mimosine in the *L. glauca* strains imported from eight countries (77), justifies such a study.

The plants used in forestry, agriculture and cattle farming in Indonesia vary in the same locality from two meters to well over ten meters in height (3, 25). The so-called "lanang" type has twice the stem diameter and crown as the ordinary one (18).

Valuable Characteristics

L. glauca has been found in many respects to be one of the most amazing aid-plants known for tropical agriculture and dairy farming in general. Illustrating its especially favorable characteristics, the following data in connection with soil conservation may be presented.

Root System. The root system of this legume consists of a very strongly developed tap-root which grows with great rapidity. Its few laterals grow downward at a sharp angle with the tap-root. Diggings showed that in young volcanic, well weathered soil under humid conditions—conditions which do not stimulate the plant to reach for deep water-carrying strata—its main roots grow to a depth of over two meters on seedlings one year old, and to over five meters on trees five years old (10, 13).

Due to its rooting habit, it can be planted in very close stands. A further important characteristic is that the roots pierce compact strata, thus breaking up and aerating impervious soils (16, 18, 35, 45, 67).

L. glauca has good nitrogen-fixing properties, provided that nodule-forming, nitrogen-fixing bacteria are present in the soil (3, 4, 8, 23, 25, 29, 32, 35). It will grow without the nodule bacteria, but it then competes with other plants for nitrogen. This defect can be remedied easily by inoculating the soil with some dirt taken from a place where the legume does form nodules (16).

With its deep growing root system, *Leucaena* can obtain nutrients from strata which are not accessible to most other plants, and, as we shall point out later, gradually these elements are supplied to the topsoil through its dropped leaves which readily decay. *Leucaena* thus can be compared with a pump which pumps up the nutritive elements from deep soil strata to the surface soil. The plant has two unique features. The first is the fact that it grows readily and thrives on the steepest, rockiest slopes, where its roots can be found penetrating deep between cracks (17, 25, 67). The second is that it is found under natural conditions in semi-arid regions (17, 21, 67).

These various characteristics make *L. glauca* peculiarly fitted for erosion control in cropped land and for water conservation (2–4, 8, 14–16, 36, 37, 40, 43, 47, 50, 61–64, 74, 75). Due to the fact that it never causes root competition under normal soil and climatic conditions, it has become a matter of routine in the last 25 to 30 years to interplant it with such perennial crops as coffee, quinine, cocoa and tea; and in the last 15 to 20 years, with rubber, oilpalm, coconut, fibres (agave), etc., also. It has also become more and more the practice to use this legume as an aid-plant in fruiticulture.

Cases of water competition have, however, been known during extreme conditions of drought in coffee and rubber plantations in the monsoon regions of East Java (11, 71, 72). Drastic pruning towards the end of the rainy season and if necessary also during the dry season stops this (11, 71, 72). Leucaena's most important feature is that it stands even frequent stumping under low rainfall conditions (67, 71, 72). This characteristic is proving useful for instance in dairy farming in Hawaii where special *Leucaena* pastures in the dry regions are established to provide cattle forage (67).

FIG. 2. Young *Leucaena glauca* hedges between young tea. (After J. J. B. Deuss, 1921.)

In forestry *Leucaena* is a valuable aid-plant in teak culture, in reforestation and in water conservation (9–13).

Water conservation combined with timber use has become an important economic advantage in the reforestations in Indonesia. *Leucaena* allows lumbering without affecting the water supply for irrigating the rice which is dependent on a regular supply of water stored by the mountain forests. Furthermore, the chemical composition of the water is improved by the legume. By interplanting the reforestations with *Leucaena*, the welfare of the population is improved, while at the same time a more economic use can be made of the land required for water conservation because the topsoil is deepened and enriched by this legume.

Wood. The wood of *Leucaena* is hard and close grained. As a timber it has little value. Charcoal made from it is of high quality, and as a fuel it is greatly favored by the Indonesians for its high caloric value. In the Philippines *Leucaena* charcoal is in certain regions an important product (3, 25, 46, 60, 66, 74). Some figures on volumetric weight, moisture content, ashes and combustion value of the wood in comparison with other fuels are presented in Tables I and II.

L. glauca is highly wind-resistant, and, provided the soil allows its root system good anchorage, this legume, planted in hedges across terrains which have to be protected against the ill effects of high winds, has given excellent results in Indonesia (35). The plant is often used as a wind protection for young plantation crops (35, 74, 75). It is utilized with success even against wind erosion on certain soils in East Indonesia, which, after tillage, easily pulverize during the dry monsoon (17).

TABLE I

VOLUMETRIC WEIGHT PER CUBIC METER OF *LEUCAENA GLAUCA* WOOD IN COMPARISON WITH OTHER FUEL

Erythrina spp.	(wet)	247 kgs.
Erythrina spp.	(air dry)	185 kgs.
Coffea robusta	(wet)	370–617 kgs.
Coffea robusta	(air dry)	370 kgs.
Leucaena glauca	(wet)	550 kgs.
Leucaena glauca	(air dry)	370 kgs.

(After "Vraagbaak voor de Koffiecultuur en Koffiebereiding," 1941)

On plantations the wood is used for fuel. In coffee, tea and cacao plantations harvesting and rejuvenation methods have been developed for *Leucaena* in order to provide for a regular supply of fuel for the factories (60, 74, 75).

Soil-Building Qualities. Part of the nutrients which *Leucaena* obtains from the deeper soil strata are gradually deposited in the top soil through its decaying leaves (3, 4, 7, 8, 14, 16, 19, 35, 43, 76). Analyses of the mature leaves show that their total N-content varies from 1.5% to 2.5% of the dry weight; in young leaves, even up to 4% (3). As *Leucaena* sheds its leaves regularly, valuable organic matter is formed in the top soil (1–4, 15, 23, 24, 32, 35, 36, 42, 47, 49, 59, 76). It was further found that it can stand pruning and even stumping almost indefinitely (3, 4, 14, 15, 29, 32, 35, 38, 67, 71, 72). There are examples of *Leucaena* hedges 40 years old, regularly stumped and cut for forage at frequent intervals during all those years, which are still going strong (67). Thanks to this fact the amount of organic material can be increased enormously.

Based on these findings, two ways of utilizing *L. glauca* for permanent soil improvement are used in Indonesia:

1. The first is the natural way, by which *Leucaena* is left undisturbed and the improvement is obtained over a long period of natural growth, during which time the amount of organic material brought to the top soil is entirely dependent on the natural frequency of leafdrop. This way is the cheapest and

TABLE II

COMBUSTION VALUE OF *LEUCAENA GLAUCA* WOOD AND OTHER FUELS USED IN PLANTATION FACTORIES IN INDONESIA

Description of fuel	Moisture content	Ashes	Combustion value
	Percent	*Percent*	*Calories*
Softwoods, air dry	30.0	1.2	2,700
Coffee (Robusta, dry)	9.2	2.45	3,915
Leucaena (dry)	10.9	1.62	3,895
Hevea brasiliensis (dry)	11.3	2.44	3,890
Coffee hulls	11.3	1.77	3,885
Red coffee bean peels air-dry	20-30	..	3,133-2,666
Red coffee bean peels, dry	12.0	5.5	3,500
Leucaena charcoal	..	1.0	7,250
Oil	..	..	10,000
Gas	..	..	11,000

(After "Vraagbaak voor de Koffiecultuur en Koffiebereiding," 1941)

is followed when a long-time investment is involved, as in reforestation or the building up of poor soils (9, 17, 19, 20, 27, 34, 40, 68, 69, 76). For example, it is used for reclaiming the waste grasslands of *Imperata cylindrica* in the Philippines and in Java (3, 9, 52).

According to recent experiments in Hawaii, such reclamation of barren lands would soon pay dividends. In long term experiments the forage yield of *L. glauca* cut at various frequencies up to six times a year showed green yields somewhat lower than alfalfa; the dry yield was the same, while *Leucaena* showed a marked superiority over alfalfa in the percentage of protein (67). The total tonnage of fresh whole forage of a *L. glauca* pasture as obtained in these experiments is presented in Table III.

TABLE III

MEAN YIELD OF FRESH WHOLE FORAGE OF *LEUCAENA GLAUCA* IN TONS PER ACRE PER ANNUM HARVESTED AT THREE INTERVALS OVER A THREE-YEAR PERIOD. THE FIGURES BETWEEN BRACKETS ARE THESE YIELDS CONVERTED BY THE WRITER TO METRIC TONS PER HECTAR (67).

Year	Cutting frequency		
	3 ×	4 ×	6 ×
1940	22.78 (55.37)	25.95 (63.07)	22.96 (55.79)
1941	23.73 (57.67)	25.50 (61.97)	27.77 (67.49)
1942	23.64 (57.46)	26.64 (64.75)	24.37 (59.23)
Mean	23.38 (56.83)	26.03 (63.26)	25.03 (60.83)

Experiments of the Netherlands Indies Forestry Service in land reclamation and reforestation with teakwood showed almost 100% increase of the teak when closely interplanted with rows of *L. glauca*, over the control plots planted to solid teak.

2. The second method is always used on plantations. In plantation crops production is stimulated as much as possible, while harvests are frequent and extended over a long period. In tea, for instance, the oldest plantings are well over 70 years of age with production still rising. Therefore, the chemical elements withdrawn from the soil by the crop of tea leaves have to be replaced as rapidly as they are taken out. *Leucaena* has proven to be an able supplier of nitrogen and to a lesser degree of phosphates; but in intensive cultures it does not supply them fast enough for profitable crops. Experiments have shown, however, that the quantity of organic material turned back to the soil by the prunings can meet the requirements for rubber and tea under ordinary culture (1, 14, 15, 28, 29, 61–63). Not only that, but usually the soil can be improved and the crop increased at the same time (3–5, 22, 29, 34, 36, 38, 40, 44, 49–51, 58, 61, 76). In this paper we need not go into this matter too far, but experience and experiments have shown that the elements which are not given back by *Leucaena* and other aid-plants, and which are added by fertilizers, are economically best utilized when the soil is kept in optimum physical and biological condition by this legume; and that lack of maintenance of the latter, with cropping

continued, soon causes deterioration of all factors involved, ultimately resulting in increasing the production cost, due to lower yields (15, 19, 20, 23, 28, 34, 36, 42, 43, 45, 51, 62–64, 65).

The Besoeki Proefstation in East Java calculated the amounts of nutritive elements returned to the soil by *L. glauca* under plantation conditions. In Table IV the amounts produced by 1000 trees per hectar, expressed as equivalents of commercial fertilizer, are presented.

TABLE IV

NUTRITIVE ELEMENTS ANNUALLY RETURNED TO THE TOPSOIL BY 1,000 LEUCAENA TREES PER HECTAR WHEN REGULARLY PRUNED EACH TWO MONTHS (59)

Elements	Equivalent to the fertilizer
Nitrogen	1,000 Kilograms of ammonium sulphate
Phosphoric acid	100 Kilograms of double superphosphate

Under normal conditions of soil and climate and normal pruning, 1000 full grown *L. glauca* trees, when pruned and topped every two months, give approximately 36,000 kilograms of wet leaves and twigs per hectar per annum.

It is easy to see that this amount of organic material greatly aids in improving the physical and chemical condition of the ground as well as the condition of the macro- and micro-organic life in the soil (4, 7, 16, 18–20, 27, 28, 34, 40, 48, 56, 63–65, 68, 69, 76).

Apart from the organic material produced by the parts above ground, pruning—especially drastic pruning—results in the death of a number of rootlets which leave behind tiny channels filled with decaying organic material. When *Leucaena* is planted in dense hedges, a number of seedlings will die in the course of years as a result of natural thinning; the roots of these plants likewise leave behind a system of capillaries, partly filled by organic material. Though the roots of neighboring plants may soon again occupy these channels, it is clear that the whole contributes to the aeration and deepening of the top soil—as has been shown on profiles (15).

The same effect follows a temporary rising of the watertable which kills any roots that are submerged and suffocates them from lack of air (16, 18).

Shade Plant. Important in connection with land reclamation is the fact that *Leucaena*, once established, shades out practically all annuals, and if not pruned, most grasses and small perennial shrubs also (67). It cannot stand deep shade itself, so that in timber reforestations and in teak plantings, *Leucaena* tends to die out, but as soon as the timber is cut it re-establishes itself rapidly by means of its tough coated seed which can remain dormant for years.

In perennial crops, such as coffee, tea, cocoa and fibres, the yields are increased by shade and can be controlled to a certain extent by varying the shade intensities. *Leucaena* in this respect is an ideal shade tree which can be shaped to fit every conceivable shade requirement (2, 14, 15, 22, 36, 47–51, 58, 59). As such this legume combines both soil conservation and production technical features unequalled by any other plant tried.

Tolerance of Soil and Climatic Conditions. Experience has taught that *L. glauca* grows in both the most wet and most arid regions of Indonesia, provided in the first place that no long periods of flooding occur, and in the second place that its roots can reach the ground water level. As to the extremes of precipitation that it can stand where it is grown for soil conservation, it is interesting to know that this legume is used in areas with 4000 mm. rain per annum as well as in regions with 700 mm. (14, 21, 51).

Escaped *L. glauca* is found in Indonesia from sea level up to 500 meters above the sea; planted, however, it occurs up to 1500 meters (3). In Hawaii

the plant is found under natural conditions up to 170 meters above sea level in the higher rainfall windward sections, and up to 330 meters in the drier leeward locations (67). The rainfall conditions under which *Leucaena* is found wild in Indonesia lie between 700 mm. and 1700 mm., in Hawaii between 625 mm. and 1600 mm. annually (3, 17, 21, 67).

L. glauca is not very specific in its soil requirements, though the growth rate is very dependent on texture and pH of the soil. It has been found that fertilizing with lime and phosphates appreciably stimulates its growth. The rubber, oil palm, fibres, quinine and coffee cultures include this legume in the fertilization program of their crops. In Indonesia the most widely used fertilizer for this purpose is a Java rock-phosphate containing 25–28% P_2O_5 and 40–45% CaO. In Hawaii fertilizer experiments showed the same Ca-P response in forage production. The fertilizers used were burnt limestone with 69% hydrated lime and superphosphate with 23% P_2O_5 (15, 16, 23, 59, 61, 67, 74, 75).

Undesirable Characteristics

Establishment. When planted from seed *Leucaena* grows slowly at first (3, 32, 67). Germination strips are therefore well prepared. In Indonesia, where most of that work is done by hand, the soil is deeply hoed and cleaned from weeds; where mechanized agriculture is practiced two deep plowings are made so far apart that weed seeds germinating after the first plowing are destroyed with the second or following ones (3, 67). Weeding is done during the first three to six months every two to four weeks, depending on the weed growth. On Indonesian plantations this is done by hand, but in experiments on mechanized soil-age cropping in Hawaii it has been found that tractor cultivating is possible (67). After the *Leucaena* seedlings are established cultivation is reduced to a minimum, since the plant suppresses all weed growth by its own shade and comes back rapidly after it is cut.

Seeding Habit. *L. glauca* is a prolific seeder which leads it to produce dense thickets. In coffee and tea culture, which are not mechanized, the numerous seedlings have to be kept in check by hand labor. The root system of the young plant, as we saw, rapidly anchors itself deep in the ground, so that pulling out the seedlings is very troublesome and they have to be slashed. The stumps soon sprout, however, making the slashing a perpetual job, thus increasing the cost of weeding (15, 35, 39, 51).

Diseases and Pests. In the Pacific tropics *Leucaena* sometimes acts as a host for a number of root fungi and parasitic insects which so far have been studied only in connection with their danger to certain plantation crops.

These root fungi are *Fomes lignosus* Kl., which attack rubber and tung oil; *Rosellinia bunodes* (B. et Br.) Sacc., *R. arcuata* Petch, and *Ganoderma pseudoferreum* Wakef., all active on tea (3, 6, 31, 53, 57, 73–75).

Though in the beginning this susceptibility was regarded as a draw-back which would limit the use of this legume to regions free from these fungi, experience has taught that the beneficent effect of *L. glauca* is far greater than the feared disadvantage.

Usually the soils in which these fungi are present are poor soils, and the evidence is becoming more and more conclusive that if introduction of *Leucaena* is done carefully the soil will be so much improved that the diseases will not increase; on the contrary, many field observations are recorded where the crop trees—apparently bolstered by the improved soil conditions—become more resistant to the diseases.

Two insects damaging coffee in Indonesia have been found to attack *L.*

glauca as well. These are *Pseudo-coccus citri* Risso, which occurs on *Leucaena* above 600 m., and *Ferrisia virgata* Ckll. This latter can, in extremely dry East monsoons, also attack tea, though this crop is not a regular host for this mealy bug (3, 74, 75). These two insects preferably feed on the young pods which, as we mentioned, form in abundance. Eradication of the pests in *Leucaena* as well as in coffee is extremely costly and never entirely successful. Moreover, they live also on many other hosts, mainly green manures, which cause reinfestation (74).

As *Leucaena*, however, is essential for both shade and soil conservation, the cost and trouble of fighting the pests have been taken for a quarter of a century until in recent years two almost sterile kinds of *Leucaena*, namely *L. pulverulenta* (Schlecht) Benth. and *L. glabrata* Rose, have been introduced. These almost seedless forms have solved the weeding problem caused by the abundant seeding of *L. glauca* (35, 39, 74, 75).

The new types were originally imported from Mexico by the Netherlands Indies Forestry Department for use in reforestation, since they were known in their original habitat for their fine, hard wood and vigorous growth, which characteristics were especially desirable for those localities where *L. glauca* showed poor growth (35, 39).

The seed listed as *L. pulverulenta*, however, segregated into various types, obviously as a result of natural hybridizing with *L. glauca* in its original habitat, since the same hybrids have been reproduced by hand pollination and by planting *pulverulenta* buddings close to *glauca* trees (35). The types used in improving the *Leucaena* stand in plantations is vegetatively propagated from some chosen by the Agricultural Experiment Station workers. They are extremely vigorous growers with straight stems and an abundance of foliage, and very closely resemble the description of the species (39). Further selection work to separate the true breeding species is in progress, but the work goes slowly, owing to the poor seeding qualities of these most desirable types. As these forms, however, proved to bud easily, even on old *L. glauca* trees as stocks, the old stand on plantations is being converted by topworking the *glauca*. Budgrafted in the dry season, the success varies between 90% and 100%. During the wet season the success is almost nil (74, 75).

Also some hybrids between *L. glauca* and *L. glabrata* were very useful, being almost seedless and very vigorous, and subject to propagation by topworking on the existing *L. glauca* stand (60, 74, 75).

The above mentioned diseases and pests never succeed in eradicating *L. glauca;* its abundant seeding habit helps it to survive.

For reclaiming depleted and eroded soils in combination with reforestation, the free seeding *L. glauca* is of the greatest benefit. Its natural way of growth results in a close mixing with the young timber, yet by the time the harvesting of the timber starts, the legume has been thinned as a result of the shade of the tall trees, so it does not hinder the work.

Abnormal Growth. With rising elevation above sea level, leucaena's growth becomes slower and the plant tends to remain a shrub (3, 67). This condition also obtains on acid soils (75). Especially in tea gardens it never does too well, since tea has its optimum production at a pH between 4 and 6.5 and at a high elevation above sea. Here it has been found that topworking *L. glauca* with the extremely vigorous *L. pulverulenta* and *L. glabrata* hybrids improves the leucaena stand, inducing an amazing growth, thus making possible sufficient shade and adequate green manure. In

Java *glauca* stocks budded when three years old with *L. pulverulenta*, had after two years an average girth 50% larger than the controls; after four years they were 100% larger (60).

In the high coffee localities both top-working of the backward *L. glauca* with these improved varieties (60) as well as conversion with the "lanang" type *L. glauca* are practiced on a large scale (18). The coffee soils are neutral or near neutral, so that here the stunted growth of *L. glauca* is a result mainly of the high elevation above sea level.

Propagation

Leucaena glauca is easily multiplied by seed which it produces in abundance in the dry season (3, 23, 32, 67). In humid tropical climates, unless stored brittle dry in soldered drums, the seed loses 50% of its viability in four to five months time (23). It is small in size; it takes about 21,000 seeds to weigh one kilogram; 95% have a hard coating (23, 26, 32, 33, 54, 67).

For planting the seed should be treated with either hot water or concentrated hydrochloric or sulphuric acid, or it should be subjected to mechanical scarification (23, 54, 67). The latter method is preferable, since it prevents failures and accidents due to mishandling the hot water and the acids. Scarification permits both hand sowing and mechanized sowing with any standard drill (67).

Germination starts within seven days and is ended after about two months (3, 23, 24, 32, 54, 67). Normal seed pretreated as described above should have a viability of 88% (26, 41, 54).

Sowing is usually done towards the end of the dry season, but in certain regions in the Pacific seedlings may suffer badly from attack by *Rhizoctonia*, and to avoid this disease, the seed is therefore planted in the middle of the dry season (74).

Leucaena glauca can be propagated also as cuttings and stumps. Stem and branch cuttings give very little success and are of no value (3, 67).

Stumps, however, with a diameter up to ten centimeters and a length up to four meters, take readily when left in the nursery after stumping until the dormant buds on the stems show activity (3, 64, 74, 75). The roots are dug out as deep as possible, but not shorter than 20 cm. The cost of transplanting increases with the size, and so do the chances of die-back when after transplanting unfavorable weather conditions occur. Loss of stumps as a result of this, however, almost never occurs. Usually the plants regenerate from the rootcollar. Short stumps endure unfavorable weather conditions better than high stumps.

High stumps are used to interplant in existing plantings of coffee, cacao, tea and fibres, or in thickets of undesirable vegetation in land reclamation based on long-term conversion (3, 29, 74, 75).

Seed planting is cheapest and gives the highest yields of green manure and forage, so that this method of establishment is preferable wherever no special purpose requires stump planting (3, 29, 30, 32, 67).

Planting Systems in the Pacific Area

Some of the more commonly pursued planting systems for *Leucaena glauca* in the Pacific area may be noted as follows:

1. For the sole purpose of erosion control in denuded and eroded country, hedges are established every ¼ degree of slope. Since under poor soil conditions *L. glauca* starts to bear seed within a year after planting from seed, it will spread automatically and gradually drive out weeds and most of the grasses, and finally cover the land (17). Cattle, goats and sheep must be kept out of the plantings as long as the tops of the hedges are in reach of the animals, as

the latter are very fond of the young shoots of this species, as well as those of the other two mentioned species (3, 17, 23, 67, 70).

2. For reforestation between rows of timber, strips are sown to the legume (12).

3. In tropical and subtropical agriculture one or more rows of *Leucaena* are planted, preferably from seed, between the crop rows, depending on the planting system of the latter. The hedges are pruned and the green manure mulched under the crop trees. In sloping country the hedges are naturally planted on the horizontal along the outside of the bench terraces, or directly below erosion ridges on less sloping terrain (14, 18, 30, 36–38, 40, 42, 47, 49, 58, 64, 65, 74, 75).

Suggested Use in the States

Since *Leucaena glauca* is now growing wild in Texas, Arizona and Florida, and *L. pulverulenta* in Texas and Arizona (39), it is the author's opinion that their introduction into soil conservation, horticulture and pasturing in these States does not involve any risk. Now that the Hawaii Agricultural Experiment Station has worked out the mechanized way of planting, establishing and harvesting these plants, economic utilization of land unfit for other crops is provided one more solution. For instance, in arid regions, land unfit for pasturing could be transformed through mechanized establishment of irrigated leucaena pastures and mechanized harvesting of the soilage crop by means of a corn binder (67). Even to be reclaimed is eroded country that might soon pay dividends with this method.

In horticulture we expect that *L. glauca* can save part of the cost of fertilization by using it for green manuring. In establishing a leucaena cover instead of the now used covers of grasses and other legumes, or a mixed cover with these, and harvesting the green manure close near the ground, we would combine the benefit of a permanent cover, supplying easily decomposing organic material, with appreciable amounts of nitrogen and phosphoric acid.

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Comparison of Seed and Vegetative Propagation Methods for Red Squill

Seed propagation was found more profitable than any of three vegetative methods investigated for multiplying this source of a very specific raticide.

D. L. VAN HORN[1] AND W. E. DOMINGO[2]

Introduction

Red squill (*Urginea maritima* (L.) Baker), a member of the lily family, is native to countries bordering on the Mediterranean Sea. Its use as a raticide has been known in those areas for centuries and it is now commercially in use in many parts of the world, especially in Europe and North America, because it is the most specific of the raticides now available. A review of all phases of the use of this plant for rat control is given by Crabtree (1). As part of an investigation of the possibilities of commercial squill culture, a study was made of its propagation by seed and vegetative parts. The results of this study should indicate the most practical method for commercial squill culture and also determine the breeding method to be used in attempting to improve the crop by specifying the degree of homozygosity for toxicity factors that will be necessary in superior varieties.

Materials and Methods

The bulbs used in this study were received through the Division of Plant Exploration and Introduction in July, 1943. They were from one to four and three-fourths inches in diameter and were non-toxic. Ten of the bulbs produced seed in late summer of 1943, and this seed was used together with the parent bulb material for the propagation study.

Since red squill grows normally during the wet winter season and is dormant in the hot dry summer, the study was carried out in the greenhouse at Beltsville where bulbs begin growth in September and go dormant during June. In addition to propagation by seed, three vegetative methods were used. One was that suggested by Traub's work with amaryllids (2), which involves cutting each bulb radially into 16 segments. The resulting segments consist of longitudinal pieces of several scales attached to a small portion of the basal stem called a " plate " or " pad ". Another method used was that suggested by Luyten's work on hippeastrums (3), in which the major portion of the plate or pad is removed from the bulb and the individual scales pulled off and planted base down. In this method no stem tissue is planted. The third method was a modification of the Luyten method, each scale being divided into an upper and a lower half and the halves planted base end down.

In order to reduce to a minimum the effect of variation in the growth potentialities of the individual parent bulbs, the same amount of bulbous material was used for each of the several methods of

[1] Agronomist, Division of Tobacco, Medicinal and Special Crops, BPISAE, U. S. Dept. Agr., Beltsville, Md.

[2] Formerly agronomist, Division of Tobacco, Medicinal and Special Crops, BPISAE, U. S. Dept. Agr., Beltsville, Md.

vegetative propagation. This amount was 2,310 grams because that was the weight of the ten bulbs from which the seed used was obtained. As a means of ready reference the several methods of propagation used are designated as follows:

A. Propagation by seed.
B. Vegetative propagation.
   1. Traub method—wedges (October planting).
   2. Traub method—wedges (December planting).
   3. Luyten method—scales.
   4. Luyten method—scales (modified).

For treatment A, 3,089 seeds, weighing 8.79 grams, were planted in a sand-soil-muck mixture in greenhouse flats on October 23, 1943. Germination occurred in a few days, and the cotyledon soon reached a length of from one to three inches. By December 14 a few of the seedlings had produced the first flat leaf which is extruded through the tubular cotyledon near its base. Transplanting to two-inch pots on this date was prompted by the presence of a damping-off disease. At the end of the first growing season 680 seedlings had survived.

The wedge-shaped cuttings used in the Traub method (B–1) were planted in similar soil on the same date. A second planting of this kind of material was made in sand in December, 1943 (B–2), because some of the pieces planted in October were rotting. The scales obtained by the Luyten method (B–3) and its modification (B–4) were planted base end down on October 23 in the same kind of soil as the others planted on that date. In the case of the scales from B–4, bulblets were formed only on those segments that originally comprised the lower half of the scale. Table I summarizes the data taken when the bulblets were examined on May 24, 1944, and when they were taken up on July 12, 1945.

Since the large number of bulbs formed from seed made it impracticable to maintain the whole population, this lot was cut down to one-sixth of its size in May, 1944. Thus only one-sixth of the bulbs originally formed by the seed method were carried throughout the rest of the study. On January 12, 1945, the bulblets were transplanted from thumb

TABLE I

PRODUCTION OF BULBLETS BY DIFFERENT METHODS OF PROPAGATION BY MAY 22, 1944, AND JULY 12, 1945

Method	Number of seed or parts planted	Number of bulblets formed by 5/22/44			Production of bulblets by 7/12/45		
		With leaves	Without leaves	Total	Number	Weight (grams)	
						Total	Per bulblet
A. Seed	3,089	680	..	680	612*	1,764*	2.9
B. Vegetative propagation							
1. Wedges 10–23–43	132	53	28	81	62	378	6.1
2. Wedges 12–30–43	151	19	39	58	42	210	5.0
3. Scales	282	17	57	74	96	358	3.7
4. Scales cut transversely	524	37	44	81	53	138	2.6

* Represents observed value multiplied by 6, since this population was reduced to one-sixth its original size in 1944.

pots to sand and soil mixture in double depth flats.

During the 1944–45 winter growing season a number of bulblets which had not yet sent up leaves on May 24, 1944, did so, and the number of bulblets formed from some of the treatments thus is higher than was indicated at the end of the first growing season.

The bulbs were not dug, weighed and re-set at the end of the 1945–46 growing season because it had been observed that lifting the bulbs and cutting off the roots to weigh them had seriously retarded growth. At the end of the 1946–47 growing season it was apparent that the bulbs were severely crowded in the flats; hence they were dug and re-set in new soil, with each flat of material given twice its original space.

Growth was good during the 1947–48 growing season, but in July, 1948, it was apparent that the bulbs were again crowded in the flats, and, since additional space was not available, the bulbs were dug and the experiment terminated. The number and weight of the bulbs is given in Table II.

TABLE II

NUMBER AND FRESH WEIGHT OF BULBS HARVESTED JULY 5, 1948

Method	Number of bulbs	Fresh weight (grams)	Weight per bulb (grams)
A. Seed*	462	17,028	36.9
B. 1. Wedges 10–23–43	54	2,807	52.0
2. Wedges 12–30–43	33	2,720	82.4
3. Scales	59	2,157	36.6
4. Scales (cut transversely)	41	2,126	51.9

*Represents observed value multiplied by 6 since this population was reduced to one-sixth its original size in 1944.

Discussion

Had all bulbs started from seed been retained, there would have been 462 bulbs, weighing about 17,000 grams by the summer of 1948, whereas the vegetative methods produced from 2,126 to 2,807 grams of bulbs from equal weights of parent bulb. Thus it is obvious that propagation from seed produces many more bulbs and much more weight than do the methods of vegetative propagation used here.

It can be seen from Table II that there was a larger number of bulbs per flat in the seed propagation method than in the others. It would seem apparent that crowding was greater in this case than in the other methods, and the seed method might have shown even greater superiority over a period of five years, had all bulbs had sufficient space available.

For practical purposes the superiority of the seed method depends on the extent to which the plants bloom and produce seed, which at present cannot be assured by any known method. Among the vegetative methods of propagation it appears that the Traub wedge method is somewhat superior, and it was noted that it is better to leave the pad on the bulb when it is cut. More bulbs resulted from cutting while in the dormant stage. The Luyten method gave more bulbs than the Traub method, but the bulbs weighed less, both in total weight and in weight per bulb. The modification of the Luyten method, cutting the scales in half transversely, had no effect on the total weight at the end of five years and apparently reduced the number bulblets started. Bulblets were formed only on the lower half of the cut scales. This

method should probably not be recommended. Not too much significance should be attached to the differences in average weight among the various treatments, as crowding in the flats was a large factor in the growth of individual bulbs.

Summary and Conclusions

A comparison was made of propagation of red squill by seed and by three vegetative methods. The same weight of parent bulb material that furnished the seed was used for each of the vegetative methods.

A greater number of bulbs and more bulbous material were obtained from a given weight of parent material by seed propagation than by any method of vegetative propagation. Over a period of five years the seed method produced a seven-fold increase, whereas in general the vegetative methods just reproduced the weight of the original parent bulbs.

Of the various vegetative methods compared, that of cutting the bulbs during the dormant period into wedges with the pad attached seemed to give the best results.

If toxicity is determined to a large extent by hereditary factors, vegetative propagation could be a method of retaining the toxicity of the parent line, but regeneration would be slow. Propagation by seed would be much faster and just as certain of maintaining toxicity if blooming can be guaranteed and if the parent lines can be developed with the toxicity and growth factors in a homozygous state.

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Utilization Abstract

Cortisone. Commercial production of cortisone, the drug which has attracted wide attention in treating rheumatoid arthritis, acute rheumatic fever and other human ailments, is still limited to synthesis from desoxycholic acid obtained from ox bile, and the output of it is still measured in kilograms per month. Since all the ox bile in the world probably would not be sufficient to supply all the cortisone for which there presumably will ultimately be a demand, other sources of raw material must be found, and the search is being continued for steroidal compounds of plants that can be converted into cortisone. Attention is directed in previous issues of Economic Botany to the possible role that members of the genera *Strophanthus* and *Dioscorea* may play in this study, and now soy beans and hellebore offer speculative possibilities.

Soy beans contain several steroids, and the problem of converting the principal of them, stigmasterol, into cortisone is now being investigated. Similar attention is being accorded jervine, a steroidal alkaloid of hellebore, *Veratrum viride*. "This member of the lily family has acquired through the years a number of colorful common names, among them Indian poke, itch weed, false hellebore, meadow poke, and puppet root. It is indigenous to North America and may be found growing on low ground anywhere from Canada southward to Georgia. The plant, which is from two to five feet in height, with long slender serrated leaves and greenish-white flowers, has played a role in early medical history. Certain tribes of Indians used it to select their chief. The brave whose stomach withstood its action longest was entitled to command the rest. It was also used in the early 19th century as a remedy for arthritis complaints and as a mild heart depressant, although its toxicity and nausea-producing qualities caused it to be abandoned eventually". (L. H. Sarett, *Chemurgic Digest 9*(*5*): *12. 1950*).

Peanuts—*Especially Their Diseases*

Peanuts have been grown in at least 38 States, have been of commercial importance in 12 of them, and in 1945 were cultivated on more than four million acres in the United States and on about 25 million acres throughout the world.

HAROLD D. LODEN
University of Georgia, Athens, Georgia

AND

E. M. HILDEBRAND
Texas A. & M. College, College Station, Texas

Introduction

The peanut, *Arachis hypogaea* L., is one of the crops in the United States which are generally considered to be of minor importance. However, a critical study of its position in the agricultural economy of certain areas reveals it to be one of great economic significance.

The importance of the peanut and its spread have a very interesting relationship to the three wars of this country since 1865. Before the Civil War growing of peanuts was limited to the coastal region of Virginia (Ferris, 1922). It is reported that the value of the crop as food was recognized by soldiers of the North and South and that upon returning to their homes after the war these soldiers took with them seed from Virginia, in many cases as food; in this manner the peanut was first introduced into other States. Ferris reported that in 1922 the peanut was grown in 38 States and was of commercial importance in twelve. The crop received its first major increase in acreage during and after the First World War, due to the critical shortage of oils and fats; and during the Second World War the acreage more than doubled that of any previous year.

The commercial importance of the peanut is also emphasized by the facts that in the areas of greatest production it is the major crop, almost to the exclusion of all others, and that nearly all American peanut production is in such localized areas. In some parts of the lower coastal plain from Virginia to Texas, and in scattered regions outside the coastal plain, peanuts are a major source of income. More than a generation ago the boll-weevil forced the community of Enterprise, Alabama, to discontinue cotton as the principal crop, and, more or less in desperation, to grow peanuts which have become so important as a cash crop that a monument was erected to the boll-weevil, the pest which forced the farmers first to grow peanuts.

The areas in which the peanut crop is of commercial importance are increasing year by year. It is therefore of prime importance that the diseases of this crop receive more attention than in the past. Where there have been acreage increases the disease factor has also increased. Consequently the diseases have been assuming more importance in areas of established production.

It is the objective of this paper to present a brief story on the origin of the peanut and on its importance as a crop, and to review in greater detail the literature concerning its diseases.

Historical and Botanical

The peanut was generally considered by most of the early investigators to

have been of African or Asiatic origin, since it was introduced into the United States by slave ships on which it was used as food for the slaves in passage (Ferris, 1922). The plant was first introduced into Virginia, and early production was centered near Jamestown. Thomas Jefferson in 1781 mentioned the crop as being grown in the Jamestown area (Corbett *et al*, 1925). De Candolle (1886), Jones (1885) and others claimed that the peanut was probably not of African or Asiatic origin, since it was not mentioned by early Egyptian or Arabic writers and there is no word for the crop in Sanskrit or Bengalese. Therefore they reported, since several other species of *Arachis* were known in Brazil, that the common peanut, *A. hypogaea*, is possibly a native of Brazil. Corbett *et al* (1925) suggested that a New World origin was definitely indicated when E. G. Squier and W. E. Safford independently found peanuts in Inca graves in South America in 1887. Vavilov (1926) considered the peanut to be of South American origin.

Mendes (1947) made a complete cytological investigation of most of the species of the genus *Arachis*. He has located the center of origin in the State of Mato Grosso, Brazil. He concluded that all cultivated varieties have $2n = 40$ chromosomes and belong to two species, *A. hypogaea* and *A. nambiquarae*. He also reported that a number of wild species, all with $2n = 20$ chromosomes, are found in the State of Mato Grosso which for the most part is unexplored and inhabited only by Indians. In this same region the Indians were found cultivating peanuts, all with $2n = 40$ chromosomes. As a result of his findings the cultivated peanut must be considered of a tetraploid nature. It seems likely that *A. hypogaea* arose spontaneously by chromosome doubling from diploid forms in the State of Mato Grosso where peanuts are indigenous.

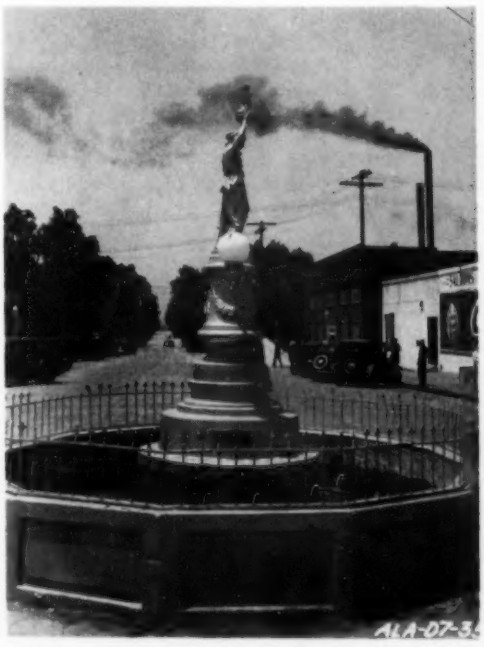

FIG. 1. Monument erected in Enterprise, Coffee County, Alabama, to the boll weevil which in the early 1900's compelled the local farmers to forsake cultivation of cotton and induced them to turn to peanut culture. The inscription reads: "In profound appreciation of the boll weevil and what it has done as the herald of prosperity, this monument is erected by the citizens of Enterprise, Coffee County, Alabama. December 11, 1919".

Mendes reported chromosomes numbers in *Arachis* as follows:

Species	Chromosome number ($2n$)
A. hypogaea L.	40
A. nambiquarae Hoehne	40
A. prostrata Benth.	20
A. marginata Gardn.	20
A. marginata Gardn. var. *submarginata* Hoehne	20
A. Diogoi Hoehne	20
A. Diogoi Hoehne, sub-species *major* Hoehne	20
A. villosulicarpa Hoehne	20

Hoehne (1940) recognized the following species:

1. *A. tuberosa* Benth.
2. *A. guaranitica* Chodat & Hassler

3. *A. Diogoi* Hoehne
   forms: *typica* Hoehne
   subglabrata Hoehne
   sericeo-villosa Hoehne
   submarginata Hoehne
   minor Hoehne
   sub-species: *major* Hoehne
4. *A. angustifolia* (Chodat & Hassler) Killip
5. *A. helodes* Mart.
6. *A. villosa* Benth.
7. *A. villosulicarpa* Hoehne
8. *A. prostrata* Benth.
   sub-species: *Hagenbeckii* (Harms) Hoehne
9. *A. marginata* Gardn.
   form: *submarginata* Hoehne
10. *A. nambiquarae* Hoehne
11. *A. hypogaea* L.
    forms: *typica* Hoehne
    macrocarpa A. Chev.
    microcarpa A. Chev.
12. *A. glabrata* Benth.
    forms: *typica* Hoehne
    major Hoehne
    minor Hoehne

The common peanut, *Arachis hypogaea*, is the species of commercial importance, and all subsequent discussion in this paper concerns it alone. A dozen varieties are known and grown in the United States, classified as follows (32):

Size of pod	Type of growth	Varieties
Large	Runner	Virginia Runner
		North Carolina
		African
	Bunch	Virginia Bunch
		Jumbo
Small	Bunch	Spanish
		Small Spanish
		Improved Spanish
		Valencia
		Tennessee White
		Tennessee Red
		Georgia Red

The bunch type has pods clustered about the base of the plant; in the runner type the pods are scattered along procumbent rooting stems.

The peanut is known by a number of common and local names. Among those most frequently used in the southeastern United States are "goober", "goober pea", "ground pea", "groundnut" and "pindar". It is generally referred to as "groundnut", "earth-nut" and "peanut" by investigators in Europe, Africa and Asia (Hector, 1943).

The principal botanical features of the peanut, as reported by Hector, include the following: a well-developed tap root with many laterals which are few in number near the surface, root hairs being absent; the central axis is erect, the laterals, more or less procumbent in the runner types, being prostrate from the beginning, and the bunch types having more or less erect laterals in the beginning, which later tend to become prostrate; pinnately compound leaves; flowers complete, single or in clusters of two to four in the leaf axils; self-pollination and self-fertilization the rule, accompanied by a marked tendency to cleistogamy; mature seeds elongated and cylindrical, or ovoid, diagonally flattened at one end and short-beaked, rounder at the other. On germination the hypocotyl elongates and brings the cotyledons above ground. The terminal bud develops first, quickly followed by two lateral buds. Some varieties have seeds which germinate immediately, others after a definite period of dormancy. This characteristic of the peanut seed to have a dormancy period in certain types and not in others is of economic importance, since in the strains which possess no dormancy after maturation the seed must be harvested immediately, lest it germinate, thereby materially reducing the yield of marketable seed. This character is of particular importance because the Spanish types, used principally for shelling and oil, have no dormancy period. In contrast, the less valuable, large podded runner types, used for hogging-off and having less percentage

of oil, possess a long period of dormancy which allows a greater spread of harvest time after maturation. Stokes and Hull (1930) found the dormancy character to be inherent and incompletely dominant to non-dormancy. Other comparisons between these two main types of commercial peanuts in the United States are:

Character	Spanish	Runner	Reference
Percentage of hull ..	17.74	14.70	(3)
Oil per ton of seed..	700 pounds	500 pounds	(32)
Percentage of oil	52.5	43.3	(71)

Production Statistics

Production statistics are generally considered to be of little direct relation to the diseases of the peanut, which constitute the principal topic of this article. It is believed, however, that such data will be of value when it is considered that the literature published to date on the subject of peanut diseases is rather scant, even when compared to other relatively minor agricultural and horticultural crops. It is possible that the reason for this condition lies not in the fact that the disease problem in peanut production has not been of particular importance, but rather that the acreage devoted to the crop has been concentrated in a relatively few areas. Secondly, due to this localization, the crop has not received adequate attention in plant pathological research.

The regions of greatest peanut production in the United States are indicated in Figure 2, which also shows the extent of the area in the United States adapted to production of the peanut crop, as suggested by Beattie (1920).

The relative value of the peanut crop to the American farmer, and its increase in value by five-year intervals, are given at the top of the next column (66).

Year	Production (million pounds)	Value (million dollars)
1870	16.0	2
1875	25.0	3
1880	38.7	2
1885	59.5	3
1890	94.0	6
1895	172.0	6
1900	300.0	11
1905	396.0	18
1910	519.0	25
1915	630.0	28
1920	497.0	27
1925	485.0	24
1930	425.0	15
1935	824.0	26

An indication of the relative increase in peanut acreage due to the Second World War may be obtained from the next figures relative to the acreage planted in the United States, 1925–1945. Of particular interest is the trend of "picked" *vs.* "not picked" acreage. Not picked acreage is that which is "hogged-off", while picked acreage refers to that from which the peanuts are harvested for commercial purposes. The data were obtained from the 1947 Yearbook of Agricultural Statistics, United States Department of Agriculture:

Year	Total Acreage (1,000 acres)	Not Picked (1,000 acres)	Picked (1,000 acres)
1925	982	..	..
1930	1,881	808	1,073
1935	2,546	1,049	1,497
1940	3,108	1,056	2,052
1945	4,100	940	3,160

The world-wide importance of the peanut crop for food and feed is indicated from the 1945 world production figures (U. S. Dept. Agr., Yearbook of Agr. Stat., 1947). The relative value of the peanut as a human food may be obtained when it is noticed that such thickly populated areas as India and China, with relatively few livestock, are the principal areas of world production. (See tabulation at top of first column on p. 358.)

Country	Acreage (1,000 acres) Harvested
United States	3,160
Mexico	62
North America (total)	3,400
Burma	559
China	3,214
India	10,574
Asia (total)	15,000
Africa (total)	2,460
South America (total)	600
Australia (total)	19
Europe (total)	35
World Total	24,600

Virus Diseases and Similar Maladies

Peanut Rosette Virus. This disease of peanuts has been designated "Arachis virus" and "peanut rosette virus" (Weiss, 1945), "ground-nut curl disease" (Zimmermann, 1907), "ground-nut rosette" (Storey and Bottomley, 1925), "ground-nut clump disease" (Sundararaman, 1928) and "ground-nut leprosy" (Trochain, 1931).

Peanut rosette is distributed widely throughout the peanut-growing regions of equatorial and southern Africa (Storey and Bottomley, 1928), in the peanut-growing area of Texas (KenKnight, 1942), and is found in Java, Madagascar and probably India (Weiss, 1945). Weiss (1945) also reports a similar disease of virus aspect in Brazil, Russia, Australia and Argentina.

The disease has been reported only on the common peanut, *Arachis hypogaea*, and occurs on most varieties of it. According to Weiss (1945), the varieties Philippine White and Philippine Pink are resistant.

Storey and Bottomley (1928) describe the disease as follows: "Rosette disease produces a striking modification in the peanut plant; the whole plant may be little more than a close tuft of small curled leaves, forming a cushion of a few

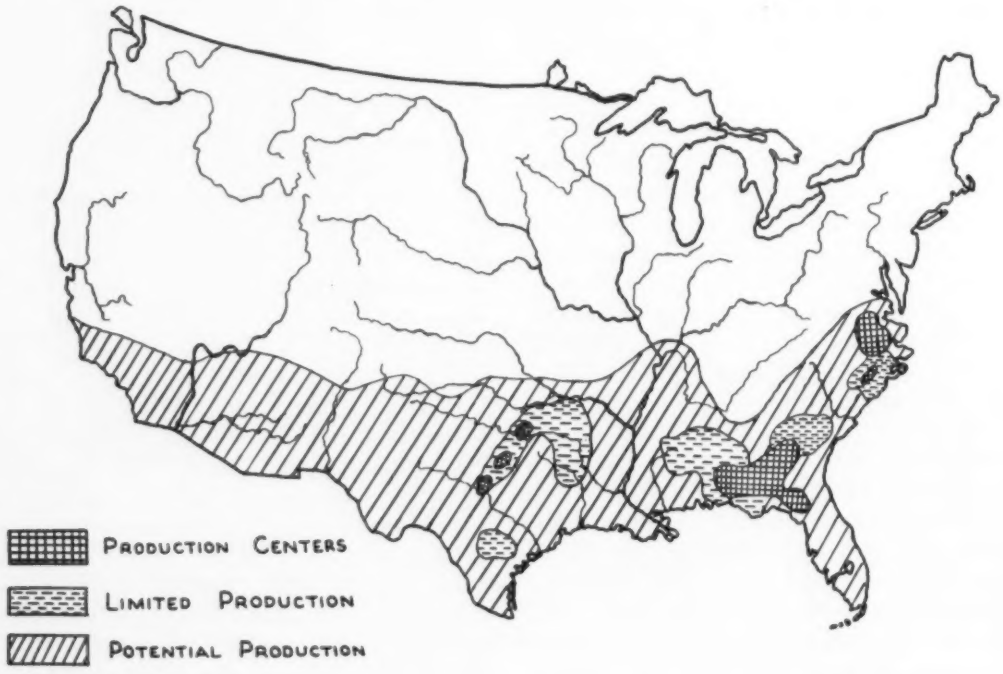

FIG. 2. Areas of present and potential peanut production in the United States.

inches in diameter, or its branches may be of some length, but bear terminally similar tufts of small leaves. Accompanying this rosette form of injury is more or less yellowing usually distributed over each of the young leaves, but occasionally confined on each leaf to irregular areas, separated by normal green tissue, producing a mosaic-like pattern. The abnormalities which have brought about this divergence from the usual form of the plant may be analyzed into the following symptoms: a cessation of the growth of the axis, a reduction in the length of the petiole and in the size of the leaflets, and chlorosis, malformation, and curling of the leaflets. We have found no evidence of true proliferation; although axillary buds appear to be forced into growth, and these developing into short shoots with small crowded leaves, add to the general rosette appearance". They also reported that the first sign of the disease is a faint indefinite mottling of the youngest leaflets, with the next leaf to open predominantly of a pale yellow color upon which the veins form a green network.

Hayes (1932) reported two distinct types of symptoms. The chlorotic rosette of Hayes has the same symptoms as those given above by Storey and Bottomley. He also observed a green rosette type in which there was no chlorosis, with the leaves darker than normal green, undersized and tending to be roundish.

Weiss (1945) states that Brooks (1932) believed two distinct viruses to be involved, since the chlorotic syndrome can be superimposed on the green rosette type, or vice versa, by grafting. He also gives symptoms of a third type in which the leaves remain normal in color but much reduced in area while becoming thickened. Besides, the branches were thickened and curved. A fourth type was also mentioned by Weiss and called "clump", in which none of the plant organs develops normally, probably due to early infection. Seed production was arrested in all forms of the rosette. Storey and Bottomley (1925) observed no case of true recovery from the disease, although at certain seasons rosetted plants may be difficult to distinguish from those stunted by other causes. Yu (1939) reported that mottling and leaf deformity sometimes were pronounced, but that in general, less than one percent of the plants were stunted.

In this review it appears that the disease can be transmitted by grafting and by the insect vector *Aphis medicaginis,* but not by juice inoculation. Symptoms were noticed in 13 days. Storey and Bottomley (1928) state that their evidence tended to indicate seed transmission, although, from the practical point of view, transmission by the seed appears to be excluded. They also stated that the disease was not transmitted by soil or by juice inoculation, but that transmission could be effected by grafting. They observed that the regions in which severe outbreaks of the rosette occurred were subject to heavy infestations of *Aphis leguminosae* (*A. medicaginis*), and investigations supported the suspicion that these insects were insect vectors. Two species of leafhopper were also tested as carriers of the disease, but failed to transmit. The authors postulated that the virus overwinters in diseased plants which have arisen from autumn-germinated seed and which survive the drought and frost of winter. Upon these plants the aphids may spend the winter. Thus in the spring winged aphids could become disseminated from the overwintering plants and cause localized infections in the peanut fields. Later in the season epidemic spread of the rosette occurred. Based on six years of peanut growing, the spring rosette infection was most severe in seasons following winters of exceptional rains.

According to Hayes (1932), the pres-

ence of weeds definitely inhibits rosette, and clean plots with wide spacing showed more rosette than close spacing. He recommended delayed weeding, selective weeding, leaving *Pennisetum setosum* in the fields, interplanting with cereals, fallowing, close spacing and roguing of the first diseased plants as the most practical control measures. Storey and Bottomley (1928) suggest destruction of volunteer plants, removal of diseased plants and early planting dates as control measures but conclude that " The best prospect of practical control of rosette probably lies in the discovery of resistant varieties ".

Necrotic Spot. This is a disease of unknown nature but regarded by Weiss (1945) as possibly virus. It was reported by Jenkins (1941) as occurring in Georgia and possibly on material collected in Texas and Virginia.

The symptoms appear on the lower leaf surface as more or less rectangular, deep brown to almost black splotches, showing with transmitted light through the upper surface of the foliage as mosaic patterns. Symptoms also appear on petioles and young stems. A majority of the diseased plants are chlorotic to pale green, definitely stunted and poorly nodulated, and produce low yields. Histologically the dorsal epidermis and spongy mesophyll of the leaf appear necrotic. The cell walls are dark brown with cell contents slightly discolored to completely disorganized. In limited areas of the lower epidermis and spongy mesophyll there are large bodies, probably ergastic in nature, that stain pale violet to dark brown with cotton blue. The palisade parenchyma presents a " tight packed " appearance and the chloroplasts are variably chlorotic.

Jenkins (1941) also reported that, since no bacterial or fungus pathogen could be isolated from the diseased plants and since efforts to transmit it by the carborundum rubbing method were not successful, the disease may be the result of a mineral deficiency. There was no evidence that it was seed-borne. Rooted branches from diseased plants grown in complete nutrient solutions produced foliage which was progressively free from symptoms.

Ring Spot. The ring spot disease occurs in Brazil. According to Weiss (1945), it is characterized by yellow circular lesions bearing necrotic flecks in young leaves; crinkling; upward rolling; chlorotic mottling and ring and line patterns in subsequent leaves; necrotic spots or streaks in stems and arrested growth. Too little is known about this ring spot to discuss it further.

Stunt. The stunt disease, according to KenKnight (1942), is a virosis causing vein clearing, a rosette appearance and severe stunting. It was reported in southern Texas. The disease was readily transmissible by juice inoculation with aid of carborundum. Too little is known about this disease to discuss it further.

Pale Dwarf. Hartley (1927) reported pale dwarf from Java and stated that the disease was found everywhere in the West Java peanut district, on irrigated and on unirrigated land in both the East and West Monsoons. In the plantings of the natives it was nowhere found in sufficient amounts to constitute a real cause of yield reduction; however, in certain experimental plantings it was a major contributing factor in yield reduction.

This disease appears to be distinct from the peanut rosette already discussed. In infected plants the early development of roots, hypocotyl and stipules was normal or nearly so. The first leaflets were pale, much shortened, and their width more reduced than their length. The different segments of the leaf were not always equally affected. Opposite leaflets were in general very much alike in appearance, but the distal pair was sometimes more reduced than

the basal. In most seriously affected plants the petioles were also greatly reduced. Subsequent development of roots and stipules was subnormal, but only to the extent that would be expected to result from the dwarfed top. No curling or crinkling of leaves was observed, and with few exceptions the disease was not found attacking a plant whose first leaves were normal.

Tests with seed from various sources indicated that the disease is associated with seed from certain sources much more than from others. However, no evidence was obtained of transmission through the seed. The seed was obtained from a number of severely dwarfed plants, and in no case did the plants resulting from such seed exhibit the disease. It was reported that it may be associated with seed source, since there is an inverse correlation between germinative vigor and dwarfing tendency, but this may in part be due to hereditary differences.

The pale dwarf disease was reported to be of non-parasitic origin. There is some reason to suspect that it may be due to excessive heat of the soil surface after seed sowing. Anyhow it appears that something destroys or inactivates the substances needed for normal growth of the leaflets.

Bacterial Wilt

Miller and Harvey (1932) found that *Bacterium solanacearum* E. F. Sm. is one of the major causes of late season wilt of peanuts in Georgia. Fulton and Winston (1913) discovered a wilt of peanuts caused by *B. solanacearum* in North Carolina, and Stanford and Wolf (1917) studied one case in which wilt of peanuts was caused by this pathogen, while Haan (1914) reported the organism as affecting peanuts in Java, which observation was confirmed by Hartley (1925).

Hosts. According to Miller and Harvey, White Spanish, Virginia Bunch, Virginia Runner, Alabama Runner, Georgia Runner and Nambaquarie varieties of peanut are all subject to infection, with White Spanish the most seriously damaged and Nambaquarie least injured. All runner types were reported as less affected than bunch types. Stevens (1925) found that many other species of plants are susceptible, among them: *Datura, Physalis, Petunia, Nasturtium,* beans, peas, *Ricinus, Helianthus, Cosmos,* tomato, tobacco and potato.

Hartley (1925) conducted tests in Java which indicated that all American varieties are more susceptible than Javanese varieties. South American and African varieties were also found susceptible; Valencia, a North American variety, was the most so.

Symptoms. Diseased plants first turn yellow, and if the attack is severe, the plant dies. Single branches may die in infected plants. When single limbs die, death may be traced to bacterial lesions on the stem.

A field symptom is wilting of leaves and stems soon after they have turned yellow. The wilting is characterized by visible dark brown spots in the xylem and pith. It is distinguished from *Fusarium* wilt in that the latter does not enter the xylem appreciably except in extreme cases.

The lesions begin as small black spots which spread rapidly in a radial direction. Large lesions show a light slightly sunken area surrounded by a dark margin. The central part is composed of shredded epidermis and cortical tissues. Splitting is typical of old bacterial infection.

Histological observations show that the bacteria penetrate either through an insect wound or directly through lenticels, spreading laterally as well as towards the center. Epidermis, cortex, phloem, and cambium are killed, and cell walls are stained brown. Xylem vessels become packed with bacteria,

and living xylem rays are destroyed. Cross sections show that darkened areas surrounding empty vessels are cells which have become entirely occluded with bacteria. Brown areas in the pith are filled with bacteria.

Physiological Relations of Host-Parasite. High temperatures are most favorable to the growth of the organism. This has been accepted as the reason for its widespread prevalence in the southern States and its non-occurrence in the far north. It grows more rapidly in young plants during very hot weather. Plants partially affected and not killed by the wilt pathogen are most susceptible to attack by secondary organisms.

Control. Miller and Harvey (1932) used sulphur and copper sulphate in attempts to control the bacterial wilt disease. Fungicides were placed in soil before planting and later dusted on month-old plants but with negative results. Disease resistance was suggested as the most promising means of control, long time rotations as a possible means. The inefficiency of such control measures is made obvious, however, by the fact that many common weeds are also affected by this organism, and it will be virtually impossible to exclude susceptible plants for the minimum five-year period, as suggested by Stevens (1925). No work has been conducted in the United States with resistant strains, but Hartley (1925) reports that resistance has been attained in certain Javanese varieties.

Southern Blight or Sclerotium Wilt

The southern blight or Sclerotium wilt disease, caused by *Sclerotium rolfsii*, is probably the most widespread disease of the peanut crop, as well as one of its most serious diseases. The disease organism is distributed over the entire peanut belt in the United States and was isolated from diseased specimens from all areas studied by Miller and Harvey (1932). They reported one 60-acre field in which the yield was reduced 50% in 1932. Another field in which 1,305 pounds of White Spanish peanuts were harvested in 1930 suffered a reduction to only 300 pounds per acre the next year, chiefly because of *Sclerotium rolfsii*.

Name. This widespread disease is known by a number of common names, such as "blight", "Sclerotium wilt", "wilt", "sclerotial rot", "southern blight", "southern Sclerotium rot" and "Sclerotium disease of peanut". No definite terminology has been agreed upon, and it has been called many other names; among these are "fruit rot", "sclerotial disease", "stem rot" and "rot". In recent years the term "southern blight" has been applied most commonly.

Distribution. This pathogen is distributed throughout the world in peanut-growing areas, including all southern States in the U.S.A. The fungus is an air-loving soil organism and is commonly found in light sandy soils which provide an almost ideal environment (Taubenhaus, 1919). Taubenhaus (1919) lists 32 species of susceptible hosts. Reyes (1937) noted that it is widespread in the Philippines, and in a review of the literature on its distribution reported "worldwide distribution".

Miller and Harvey (1932) reported that the disease was not new on peanuts in Georgia, although its importance appears to have been overlooked. Reinking (1919) observed this disease as being important on peanuts in the Philippines. Viegas (1942) reported the organism on peanuts in Brazil.

Duggar (1911) observed that in a few localities peanuts were being killed with a Fusarium form of root rot. According to his description, the symptoms are the presence of a mass of white threads on the stem below the surface, together with the appearance of minute round whitish or brownish bodies about the size of

mustard seed around the stem close to surface of the ground. This description indicates that the disease organism may have been *Sclerotium rolfsii*.

Pathogenicity and Racial Strains. Taubenhaus (1919) reported investigations which proved the pathogenicity of the fungus. He also noted that there were no varietal or physiological strains of the organism.

Etiology. The peanut plant is subject to infection by *Sclerotium rolfsii* during its entire life cycle, but is more susceptible in early growth (Reyes, 1937). Taubenhaus and Ezekiel (1931) stated that the disease may attack plants in the seedling stage, although older plants seemed to be more susceptible.

Taubenhaus (1919) reported that abrasion of the host is not necessary for infection, particularly with young plants. His observations were that the factors of paramount importance in infection are moisture and air, and he concluded that sclerotia buried over five inches deep will not cause infection, those one-half to one inch deep being most favored. The same investigator reported that infection seems to be favored by production of an enzyme secreted by the advancing mycelial threads. No evidence was available of the mycelial threads of the advancing hyphae penetrating the cells of the host, their primary function probably being enzymatic. On the other hand, penetrations seemed to be effected by the secondary hyphal branches which usually penetrate the hosts through the stomata of the epidermis and then work inward or break directly through the epidermal cells. Difference in penetration was noted in the types of tissues infected, those with considerable starch being penetrated only with difficulty, while in softer tissues direct cell penetration was common. Taubenhaus also observed that in migrating from one host cell to another, the tip end of the mycelium attached itself closely to the cell wall and then rounded up into a small ball which developed a sharp point that pierced the cell wall. When this was accomplished the tip end again swelled slightly, straightened out and grew in the usual way.

The period of incubation, as reported by Taubenhaus (1919), was from two to four days, dependent upon the tenderness of the growing host tissue.

Infection was more severe during wet seasons than during dry seasons (Reyes, 1937). Close planting was also reported by the same investigator to increase damage from the disease. Migration of the disease organism was facilitated by light sandy soils.

The agents of dissemination of the fungus are animals, man, implements and water. Since the pathogen is a soil-borne organism, it is easily transferred from place to place by soil. Plant residues harbor mycelial masses and sclerotia, and Leach and Mead (1936) observed that the sclerotia were viable after passage through digestive tracts of animals. Rain water and surface erosion play an important part in movement of surface sclerotia. Reyes (1937) reported that spread from plant to plant was effected by contact of healthy and diseased stems.

Description of Causal Agent. Fawcett (1936) observed that the mycelium of the fungus in moist atmosphere forms a dense, white, cottony mass of threads. Later, small white tufts appear and gradually assume rounded forms, the sclerotia. These sclerotia are at first white but change through light shades of brown to very dark brown.

The sclerotia are spherical to ellipsoidal, 0.5 to 0.8 mm. in diameter, smooth and shining. The hyphae are six to eight microns in diameter, subhyaline in the interior of the host, but brown with age on the exterior. The hyphae are seldom found growing singly, but in groups which tend to anastomose and

form stands. Growth at the terminal end of each hypha soon stops, a bud develops near the terminal cell, and the side of the bud toward the terminal cell continues the growth.

Physiology and Parasitism. Higgins (1927) conducted an investigation relative to the physiology and parasitism of *Sclerotium rolfsii*. He noted that the minimum temperature for growth was near 8° C. The absolute maximum is near 40°C, but 37° C appears to be the maximum for continuous normal growth. The optimum growth temperature lies between 30° and 35° C. Growth was poor below 20° C.

Temperature relations appeared to be the limiting factor in determining the geographical range of the fungus.

Filtrates from cultures of the fungus growing on certain nutrients were toxic, both before and after boiling, to seedlings of tomato, pepper and soybean.

Injuries produced by the filtrates were very similar to those produced by oxalic acid solutions.

The toxicity of the filtrates and of oxalic acid solutions to the plants tested appeared to be due entirely to the hydrogen-ions in solution.

In parasitic attacks on the plant the fungus forms a considerable mat over the attacked portion, clinging to the epidermis by means of holdfasts. The underlying cells are killed before hyphae enter the host tissue.

Considerable quantities of oxalic acid or soluble oxalates were found in these dead cells, while none was found in healthy cells of the same plant.

The evidence appears to be conclusive that death of these cells is due to the toxic action of oxalic acid and that oxalic acid is secreted by the hyphae.

Symptoms. Taubenhaus (1919) states that the symptoms of actively growing plants affected with *Sclerotium rolfsii* are very striking. Infection generally starts at the foot of the plant from one-half to one inch below the surface. Early infection is manifested first by deep brown lesions. At this stage the host plant exhibits a slight wilting. Soon afterwards the lesions become covered with white radiating mycelium which encircles the foot of the plant. The epidermis and cambium become water-soaked at this stage but remain firm, the foliage droops, the plant loses its green color and never revives. The fungus seldom works up the stem but always down toward the main root and rootlet. If the soil is moist and the dead plant untouched, the fungus will grow out on the surface of the soil in radiating fans at the foot of the dead plant. Taubenhaus and Ezekiel (1931) later reported that within 48 hours after a plant has collapsed, the white fungus growth on the soil and on the plant will seem to disappear gradually and to be replaced by a large number of small, brownish, mustard-seed-like bodies, sclerotia. Miller and Harvey (1932) reported that in many cases only single limbs or branches died, and when such plants were pulled up the fungus was found covering the seed and roots. These same investigators observed that the above-ground mycelial mass was evident only in rainy seasons, and that in droughty conditions the fungus was confined to parts below the ground, and the mycelium was much reduced. Reyes (1937) reported that the mycelium invades the cortex, girdles the stems, turns it dark, permeates the tissues of the stem upwards, and causes the stem to shrink and die. It also invades the underground parts such as pegs and pods as well as the roots. He also reported that the mycelium of the fungus may be seen on the shells of the nuts and inside the infected cracked pods, with rotting of the infected cotyledons invariably taking place.

Varietal Resistance to the Fungus. McClintock (1917) reported the first investigations relative to resistance among peanut varieties to the causal organism. He tested six varieties of peanuts and

one hog goober, *Worandzia subterranea*, planted in soil badly infested with *S. rolfsii*, and showed that the Valencia peanut was most susceptible to infection by this organism and that Spanish, Tennessee Red and Virginia Bunch were resistant in the order named, while the Virginia Runner, African and hog goober were practically immune.

Reyes (1937) reported that different varieties of peanuts grown in an infected field showed varying degrees of infection, with wilting ranging from 31.3 to 50.7 percent of the plants. He conducted inoculation studies for three years, and the 13 varieties grown and tested for susceptibility were found to exhibit degrees of susceptibility as follows, arranged in descending order of severity:

1. Valencia
2. Macapno
3. Georgia Red
4. White Improved Spanish
5. Spanish
6. Biit
7. Cagayan no. 1
8. San Jose no. 3
9. Vigan Lupog
10. Tirik
11. Taitau
12. Virginia Jumbo
13. Virginia Jumbo (a)

He further reported that the different types of varietal response to disease development do not appear to have any relation to the habit of growth, field observations seeming to indicate that relative succulence is also a determining factor for resistance. The results of three years experiments have shown that the runner types are more resistant to Sclerotium wilt than the erect or semi-erect varieties. Ordinarily the more procumbent types would be expected to exhibit more susceptibility, and, since the reverse was found to be true, it was concluded that the question of resistance of peanut to Sclerotium wilt has no relation to the habit of growth.

Control Methods. Miller and Harvey (1932) report, "There are no known methods of soil treatment that successfully control this disease in the field. Experiments with soil disinfectants were unsuccessful. Also, the great number of susceptible plants makes it impracticable to attempt to eradicate it by crop rotation. The only hope lies in planting resistant varieties".

Taubenhaus and Ezekiel (1931) noted that this disease attacks a large number of crops, so that formulation of a well-balanced system of crop rotation becomes a difficult matter. Where the disease is severe, it is best not to grow peanuts or any other susceptible crop for at least two years. In the meantime such land should be devoted to grass crops, particularly the grain sorghums, and after harvesting, the stubble should be plowed deep and the land kept free of susceptible weeds.

McClintock (1917) observed that seed pods from diseased peanuts bore mycelium and sclerotia, both externally and internally, and suggested that the seed themselves and the accompanying trash were one means by which the disease was transmitted. It was suggested that screening to remove trash and planting only healthy heavy seed would serve as one means of control.

Reyes (1937), noting the consistent resistant reaction of Virginia Jumbo and Tai-tau varieties, stated that evidently they carried a high degree of inherent resistance, and for that reason varietal resistance appeared to be one of the most promising means of control. Other means of control suggested are burning all crop residue, avoiding scattering of diseased plants, burning diseased plants, widely spacing plantings, avoiding use of stable manure as fertilizer, rotating with non-susceptible plants, using lime and carefully selecting disease-free seed.

Leaf-spot

Leaf-spot is generally recognized as one of the most important diseases, if not the most important, of peanuts. Its only rival in importance is southern blight, caused by *Sclerotium rolfsii*.

There appears to be two leaf-spotting organisms of peanut, *Cercospora personata* (B. & C.) Ell. & Ev. and *C. ara-*

chidicola Hori. Woodroof (1933) states that both have been found attacking peanuts in Georgia and that the nomenclature of these fungi is much confused. In view of this fact and of the conspicuous absence of reference to *C. arachidicola* as a peanut leaf-spotting organism, even though such is to be expected, both of these organisms will be discussed under this general topic of leaf-spot. It is the opinion of the writer, based on the findings of Woodroof, that in all probability not all of the disease reported as leaf-spot and attributed to *C. personata* was actually due to this pathogen alone but to *C. arachidicola* in part, or a combination of both organisms.

This disease has been known by a number of names; among them are: "leaf-spot" (Taubenhaus and Ezekiel, 1931; Wolf, 1916; Reinking, 1919); "Black spot" (Roldan and Querijero, 1939; Reyes and Romasanta, 1940); and Cercospora leaf-spot (Miller, 1939; Shaw, 1939). At present "leaf-spot" appears to be the most commonly accepted name among American investigators.

Distribution. Reyes and Romasanta (1940), in a review of reported occurrence of leaf-spot of peanuts, stated that it had been reported in United States, Philippines, India, German East Africa, Ceylon, China, Japan, Italy, West Indies, Surinam, Paraguay, the Congo, Malaya and Australia. A casual observation will reveal that the above-named locations are world-wide and cover that area in which the peanut is most widely grown. Based on this conclusion it may be stated that the leaf-spot organism is world-wide in spread and is found in practically every peanut-producing area.

Importance of the Disease. Wolf (1916) estimated that as high as 35% of the leaf area of the plant is lost to photosynthetic activity as a result of leaf-spot and that this may result in yield losses from 5–20 percent. Miller (1941) reported that leaf-spot causes a 30% reduction in yield of nuts and a 40% reduction in yield of hay. Other indications of the economic importance of the leaf-spot organism may be obtained by an analysis of data relative to increases in yield as a result of effective control measures. Such data are given in other portions of this section.

Historical. According to Woodroof (1933), the first description of *Cercospora personata* was made by Berkeley in 1875 from material collected by Ravenel in South Carolina in 1855; the organism was called *Cladosporium personatum* by Berkeley. Ellis and Everhart (1885) collected material in South Carolina and Alabama, transferred the fungus to the genus *Cercospora* and named it *Cercospora personata*.

Woodroof also stated that from the original description of *Cercospora personata* until recent years other investigators have reported different morphological forms. However, after examination of material of the organism, *Cercospora arachidicola*, which was originally described in 1917 by Hori in Japan, it was suggested that this fungus is also present in the United States and that the investigators had been observing mixed cultures which probably caused the confusion.

Causal Organism. *Cercospora arachidicola.* Woodroof (1933) described this organism as follows: "The mycelium is both internal and external. No haustoria have been noted. The mycelium is both intracellular and intercellular".

"The conidiophores of *Cercospora arachidicola* are amphigenous. In young spots the conidiophores are produced almost exclusively on the upper surface of the leaf, but in older spots a few may sometimes be found on the lower surface. The conidiophores are produced in 3 different ways: first, they emerge directly through the stomata, forming a

small fascicle on conidiophores; second, the mycelium grows out between the epidermal cells or through a stoma and continues to develop under the cuticle, and from this mycelium fascicles of conidiophores are formed; third, conidiophores form from mycelium growing in epidermal cells that are later ruptured by the development of conidiophores. The bases of the conidiophore groups are usually somewhat stromatic, especially when mature ".

" The conidiophores are subgeniculate, 21.6–40.5 × 3.2–5.4 microns, yellowish brown, continuous or 1 or 2 septate. The scars marking the point of attachment of the conidia are plainly visible. The colorless or pale yelowish to slightly olivaceous, obclavate conidia measure 37.8–108 × 2.7–5.4 microns and are 4–12-septate, the usual number being 5 to 7. In dry weather the number of septations are fewer ".

" The conidia germinate in water and in slight accumulations of water on the surfaces of cover glasses placed over a van Tieghem cell. The manner in which they germinate depends upon the amount of moisture present. Under favorable conditions long germ tubes develop in about 12 hours from any of the several cells of the conidium, often several tubes from a single conidium. With insufficient moisture the cells may swell without developing germ tubes ".

" Spermagonia develop on fallen leaves late in September or early in October. At about the time the spermagonia begin to develop the internal mycelium becomes very thick-walled. In artificial media the mycelium grows very slowly, forming a dense black mass. Conidia have not been observed in culture ".

Cercospora personata. This fungus was described by Woodroof (1933) as follows: " The mycelium is internal, no external mycelium having been observed. Branched haustoria develop in the palisade and spongy mesophyll cells. Late in the season the mycelium becomes thick walled ".

" The conidiophores are amphigenous but more numerous on the lower surface, where the tufts are often arranged concentrically, especially in the larger spots. These can be seen easily with the naked eye. Elliptical spots often appear on the stems and on the leaf petioles ".

" The conidiophores appear to measure 24.3–54 × 2.7–8.1 microns and are continuous, or 1- to 2-septate, subgeniculate or shouldered, the points of attachment of the conidia being plainly visible. The color is reddish brown and the apices are often hyaline. The conidiophores develop from loosely stromatic masses of mycelium that form beneath the epidermis, frequently in the spaces beneath the stomata. The epidermis is ruptured as the conidiophores emerge. The bases of the tufts become more densely stromatic as they mature ".

" The obclavate or cylindrical conidia measure 18–60 × 5.4–10.8 microns and are 1- to 7-septate. The larger conidia are usually rather abruptly attenuated to the apex. In some instances the shorter 1–3-septate conidia are clavate rather than obclavate. The color is a pale brown and in some instances almost olivaceous. The conidia are produced singly ".

" Spermagonia develop during the fall ".

Symptoms. Woodroof (1933) states, " Both macroscopically and microscopically the 2 leaf spots attacking peanut leaves are quite easily distinguished, especially when the spots become older ". These are described in general by her as follows: " *Cercospora arachidicola* produces irregular circular, often confluent spots varying in size from 1 mm. to 1 cm. in diameter and surrounded by a bright yellow halo, blending into the green of the leaf. Initial spots are yellowish specks. The center of the older spots varies from dark brown to almost

black on the upper surface of the leaf but is usually a lighter brown color on the under surface. The yellow border is less pronounced on the lower than on the upper surface. Elliptical spots are often found on the stems and leaf petioles later in the season. . . . *Cercospora personata* spots are circular and measure from 1 to 7 mm. in diameter. Halos are wanting or are a pale yellowish green on the lower surface. Bright yellow halos develop around the more mature spots on the upper surface of the leaf ".

Taubenhaus and Ezekiel (1931) reported that " leaf spot appears as small brown spots which are particularly noticeable on the leaves of well developed plants. Affected leaves shed prematurely and therefore directly affect the quality of the peanut hay and indirectly reduce yield and quality of nuts. The spots appear first as small yellowish areas which increase in size and eventually take on a chestnut-brown color. Such spots are usually surrounded by yellow areas which fade out into the adjacent green tissue. This makes the spots stand out prominently from the green of the leaves. Infection begins on the lower leaves of the plants and spreads to the upper leaves, meanwhile spreading to the leaves of adjoining plants ".

Roldan and Querijero (1939) reported the same general symptoms given above and stated, " As the lesions attain their maximum size, they become typically black, circular spots either with or without yellow border ". This absence or presence of halo may be construed to mean that the leaf-spotting referred to by these investigators may have been due both to *C. personata* without halo, and *C. arachidicola* with halo, based on observations of Woodroof referred to above.

Reyes and Romasanta (1940) state, " Aside from the black spot affections involving the aerial parts, such as leaves, leaf petioles, stipules, the infection of the vines and pegs causes serious handicaps in the normal functioning of the plant ".

Etiology. Reyes and Romasanta (1940) report that the infection period of the disease is from a month and half after planting time until harvest time. The gynophores, if they are infected at an early stage, sustain as much adverse effects as those received by the genuine stems, because of continuity of vehicular activity, and the passage of food materials is virtually hampered by destruction and malformation of necrotic tissues. The root system being of the tap root type, the aerial portions are also subject to infection. These investigators report that probably the most serious effects of all infections is that produced on the pegs, as it directly obstructs conveyance of elaborated food needed in normal development of the underground parts, especially the pods. Infection of the pegs causes irregular maturity of the pods, and a large number of them will be relatively small, generally one-seeded and immature.

Methods of Dissemination. Wolf (1916) found that the spores of *C. personata* are wind-borne. This same investigator reported that his results indicate insects to be disseminators of the leaf-spot fungus, four orders of insects being in those which gave positive tests: Orthoptera, Lepidoptera, Coleoptera, Hemiptera. Fifty-four insects of these orders out of 75 studied gave positive results. Alimentation in insects was found not to destroy the viability of *C. personata*.

The organism was reported by Roldan and Querijero (1939) as being able to live between seasons in the soil in the form of stromata in peanut refuse. Old and new conidiophores from the stroma produce fresh conidia that cause primary infection. These same investigators report that the organism is not seed-

borne. Wolf (1914) reported the same results in Alabama.

Varietal Resistance. Higgins (1935) reported that in crosses between varieties of *Arachis hypogaea* resistant strains could be isolated and stated further that the resistance to *C. personata* and *C. arachidicola* was inherited independently. Some selections were made which were highly resistant to one fungus and extremely susceptible to the other.

Roldan and Querijero (1939) tested eight varieties for susceptibility to black spot; and none of the varieties showed a significant difference in reaction to the disease, all being infected with about the same degree of severity.

Reyes and Romasanta (1940) state, " certain varieties show a marked difference in resistance. . . . It was determined from this study that the varieties Tai-tau, Georgia Red, Valencia, San Jose No. 3, and Tirik exhibited better resistance to black spot than the other varieties in the order named. . . . Without being optimistic in the least, it seems quite probable that by the introduction and acclimatization of exotic sorts or by breeding and selection, varieties and strains possessing desirable economic traits which could resist the ravages of the disease would eventually be evolved which would contribute some efficiency and economy in our method of control ".

Control. Varietal resistance seems to offer promise as one means of controlling leaf-spot diseases of the peanut, as previously mentioned in this paper.

Wolf (1916) reported that rotation by itself is not effective under field conditions in eliminating leaf-spot. This same investigator got negative results from seed treatment with copper sulphate and formaldehyde. Shelling the nuts before planting did not reduce infection.

Recent investigations in the United States indicate that this disease may be very effectively controlled by various forms of sulphur dusts. Such dusts have not been found very expensive and are particularly economical since the advent of the velvet bean caterpillar in the southeastern United States. This insect attacks the peanut fields during the time that ordinary sulphur dust applications for leaf-spot control are made, and many farmers have added to the sulphur dust the recommended poisons for control of the peanut worm, and are applying it at the same time with no extra cost. Some commercial dusts are now on the market in which sulphur and peanut worm control chemicals are mixed together for dual control.

Shaw (1939) reported that in North Carolina in 1937 and 1938, 16 pounds of sulphur for three applications per acre, begun in late July, reduced the leaf-spot lesions by 75% and reduced defoliation 70% with a 343-pound increase in 1937 and a 217-pound increase in 1938. Bordeaux mixture and other liquids gave excellent control. Pyrethrum dust showed no fungicidal value and gave only a slight increase in hay and none in peanuts.

Miller *et al* (1939) reported that leaf-spot was controlled by copper and sulphur fungicides. Liquid lime sulphur was found to cause burning and stunting of plants. Sulphur dusts gave excellent control with no plant injury.

Shaw (1940) suggested that two-week intervals be maintained between applications and that reductions in infections were greater for this interval than for three to four weeks. Two early applications were better than four to six late season dustings. Two early were equal to three late in hay yields. Six applications were found to decrease nut yields and five to depress yield of hay. Various materials tested gave from 408 to 1000 pounds per acre increase over untreated plots.

Woodroof (1941) reported a 329.5-pound increase for dusted over undusted check, even though the undusted check

plot yield was comparatively high, being 1388.7 pounds per acre.

According to Shaw and Hebert (1941), four applications at two-week intervals of 5–20 parts of copper and 95–80 parts of sulphur, beginning July 1–10, increased yield an average of 500 pounds of nuts and 800 pounds of hay at a $5.00 per acre cost for materials and labor, which actually increased the per acre value of the crop in increased nuts and hay by $15.00 per acre.

Miller (1941) reported that dusting three times with 325-mesh sulphur proved to be best in southeastern Virginia, the nuts and hay produced being of higher quality than on untreated plots.

Woodroof (1944) wrote that a yield of 305 pounds per acre of Spanish peanuts was obtained in 57 tests using sulphur; 320 pounds in 16 tests using copper-sulphur; and 331 pounds per acre increase were obtained in 13 tests using Bordeaux mixture. The same report stated that the dusting lengthened the harvest period ten to 14 days, this being of particular importance in Spanish varieties, as previously pointed out in the present review.

Killinger *et al* (1947) suggested three applications of 20 pounds per acre at ten- to 14-day intervals of sulphur-copper mixture for effective control in the Florida peanut area. It was suggested that occasionally four applications might be needed, depending upon the weather.

Langley, Reynolds and Dunlap (1945) state that the disease may be controlled with three or four applications of 325-mesh sulphur per acre at 15–20 pounds per application. They also state that if rain occurs within 24 hours after dusting, the dust should be repeated.

Fusarium Wilt

Miller and Harvey (1932) reported a peanut wilt in southwest Georgia which was caused by *Fusarium martii* Appel and Wr. var. *phaseoli* Burk. According to them no previous reports have been made of the peanut being attacked by this pathogen.

Hosts. White Spanish, Virginia Runner, Virginia Bunch, Georgia Runner, Alabama Runner and Namberquarie varieties of peanuts were all found susceptible to the disease. White Spanish was most susceptible, followed by the Virginia forms, and the Namberquarie least, with the Alabama Runners fairly resistant. They performed no tests to determine the susceptibility of other plants but stated that Burkholder (1919) found this organism causing dry root rot on several species of the genus *Phaseolus* and also on black-eye cowpea and kulti bean.

Symptoms. Maximum infection occurs when plants are about two months old and just before blooming. Necrotic areas were found in the upper part of the root, just below the crown, the root at that point being completely rotted, brittle and easily broken. Symptoms consist of a yellowing of the leaves, followed quickly by wilting and death of the plant. Very young lesions begin as small, elongate spots, slightly sunken, with light centers and dark brown borders; as the lesion ages the root is girdled, the spot increases in size, the epidermis and cortical tissue become shredded and the root dies. Histological studies showed fine hyphae in the cortical region and in the xylem. The epidermis, cortex, phloem, cambium and xylem rays were completely destroyed, anatomical changes extending beyond the visible lesion. There was no plugging of the xylem vessels with hyphae.

Wilted plants were observed all over the field with no apparent focal points of infection. There was no evidence of the disease spreading from plant to plant.

Description of Fungus. Miller and Harvey (1932) described the pathogen

as follows: " Microconidia on aerial mycelium typically present, mostly 0-septate, 2.8–14 × 3.5–5.6 microns, 1-septate, 14–22.4 × 4.2–5.6 microns, oval to oblong, occasionally 1-septate spores constricted at septum; macroconidia mostly 3-septate, of nearly uniform diameter throughout, usually slightly broader toward base, rounded apices or slightly constricted, 24.4–39.2 × 4.2–6.3 microns. Aerial mycelium white drab; substrate on neutral agars brown to reddish brown or reddish orange on rice; chlamydospores single or in chains, verrucose when mature, 8–12 microns in diameter, globose, intercalary or terminal; conidia mostly borne in false balls at apex of long conidiophores."

Physiological Relations of Host-Parasite. The fungus produces most serious damage to young plants during dry weather. In the field the effect was to damage seriously the production of peanuts and was worse during extremely hot days, while plants were young and roots poorly developed. When rains are sufficient very little *Fusarium* damage is noticed. Burkholder (1919) describes the effect of the organism on beans in terms which Miller and Harvey state apply also to the peanut. It appears that the effect of the fungus is rather to kill and dry up the tissue as it progresses up the root, thus greatly reducing the root system of the plant. The roots that remain healthy or are able to carry on their normal functions are the surface roots. Thus if a prolonged dry spell occurs at the time of blossoming and pod production, it is very injurious to the diseased plants because the yield may be reduced over 50 percent.

Dissemination and Control. No mention was made as to possible modes of dissemination or suggested controls. Taubenhaus and Ezekiel (1931) suggested that it was possible that a *Fusarium* wilt (species not identified) noted on peanuts in Texas may be spread by seed produced in wilt-infested areas, and suggested that disease-free seed be used. Rotations were suggested in areas already infected.

Concealed Damage

" Hidden " or " concealed damage " is the term which has been used in the peanut trade to designate a condition that is not visible until the seed is broken open (Wilson, 1947*a*). Killinger *et al* (1947) observed that it is an internal condition characterized by a bitter or rancid taste in sound appearing peanuts. Garren and Higgins (1947) noted that hyphal mats are usually found between the cotyledons of seed with concealed damage and suggest that the condition is a result of a filamentous fungus. Wilson (1946) reported that " concealed " and " visible " damage are the same and that under favorable conditions for the progress of " concealed " damage disease, the disease then becomes " visible damage ".

This disease has been the subject of extensive experiments to determine its control and cause only in the past few years. The amount of damage resulting annually from it should warrant much more work than has been reported. The importance of the disease is indicated by Wilson's (1946) statement that in Henry and Houston Counties in southeast Alabama alone in 1945 the cost of concealed damage to the farmers was more than one million dollars, and that damage amounted to as much as 45% in some lots, with an average of around 10% and with over one-half of the crop marketed having over 7% damage.

According to Garren and Higgins, concealed damage results when a fungus invades the intercotyledonary space through the placenta, while most of the visible damage of a fungus nature results from the activity of fungi in the space between the shell and the seeds. A comparison of fungi isolated from

visibly damaged seeds indicated that much of the damage in each of the two types of damage is the result of the action of the same fungi, and that these fungi are normally associated with the runner peanut fruits. Wilson (1947*a*) states that concealed damage of peanuts is a type of seed decay that begins on the inside of the seed and is not visible until the seed is broken. Damaged seeds have a strong rancid taste that renders them unfit for the confectionary trade. This rancidity is associated with an increase in the percentage of free fatty acid. Most, if not all, of the infections occur in the field before the peanuts are dug. The extent to which the infection develops depends upon the way the peanuts are handled after digging.

Killinger *et al* (1947) reported that the cause of concealed damage was unknown and that variety, soil type, premature defoliation and weather influence the disease. Wilson and Wilson (1945) attributed concealed damage to the manner in which the peanuts were handled after digging. Wilson (1947*a*) further observed that the rate of curing is the most important factor affecting the development of concealed damage, since it develops fastest in peanuts containing 15–35 percent moisture. If the peanuts have ten percent or less moisture at the time they are stored, the disease makes no appreciable progress. The disease appears to be more common on land that is cropped to peanuts continually.

Evans and Poole (1938) reported that the more common fungi isolated from lesions on seed coats and shells were *Fusarium* spp., *Rhizoctonia solani* Kuhn, *Rhizopus* spp., *Botrytis* spp., *Pythium* spp., *Sclerotium bataticola* Taub. and *Sclerotium rolfsii* Sacc., with *Cephalothecium* spp., *Trichoderma* spp., *Penicillium* spp. and *Aspergillus* spp. being found in reduced numbers. Prince (1945) listed those species in which more than five colonies were produced from seed of various bunch peanuts. Those reported in 111 isolations were as follows: *Alternaria* spp., 10; *Diplodia natalensis*, 5; *Fusarium oxysporium*, 8; *Fusarium reticulatum*, 6; *Fusarium* spp. other than above, 46; *Penicillium* spp., 5; *Sclerotium bataticola*, 8; *Sclerotium rolfsii*, 6; *Trichoderma* spp., 9. *Rhizopus* spp. and other fungi were found associated with the damaged seeds in reduced numbers. Nematodes were frequently present when surface sterilized peanut seed were plated. On the basis of the fungal colonies isolated from damaged seed, Prince concluded that these fungi must be associated with concealed damage. Higgins (1944) listed *Rhizoctonia* sp., *Sclerotium bataticola*, *Penicillium* spp. and *Rhizopus* spp. as being the fungi most commonly associated with concealed damage of peanuts in Georgia. Wilson (1945) failed to agree with the findings of Higgins, cited above, and reported that in samples from 12 widely separated places in Alabama, *Diplodia theobromae* was the predominant fungus associated with the disease. This fungus was found in more than 65% of the seed plated and constituted 95% of the isolates, the other 5% being composed of *Sclerotium bataticola*, *Fusarium* spp., *Aspergillus* spp. and *Rhizopus* spp. Wilson (1947*b*) later reported isolating the same organisms from young peanuts and regarded this as proof that the young peanut fruit is invaded by the fungus soon after it penetrates the soil. He reported that 80% of the isolates from seed in early stages of concealed damage were *Diplodia theobromae* (Pat.) Nowell and that as the concealed damage developed, *Fusarium* spp. were isolated in increasing numbers, this fungus and other related molds being regarded as secondary fungi. Garren and Higgins (1947) stated that unpublished data from their laboratory showed no concealed damage organisms present, or concealed damage found, in freshly dug peanuts. Wilson and Wilson

(1945) reported 13% of 100 freshly dug samples showed concealed damage and that one sample was as high as 12 percent. Garren and Higgins concluded, "The fungi most frequently associated with peanut fruits are common soil-borne saprophytes such as *Rhizopus* sp., *Aspergillus* spp., *Sclerotium bataticola, Diplodia* sp. and species of *Fusarium*. Species parasitic on peanuts are uncommon". Wilson (1947*a*) concluded, "The fungus most frequently isolated from damaged seeds is *Diplodia theobromae*, one of the imperfect stages of *Physalospora rhodina*. Other fungi, species of *Fusarium* and *Penicillium*, *Sclerotium bataticola* and other soil-inhabiting fungi, are sometimes isolated but in most instances these fungi seem to come in as secondary invaders after the seed reaches the advanced stage of decay".

Garren and Higgins were able to produce concealed damage in peanut seeds by inoculation of surface-disinfected seeds with *Diplodia* sp. and *Sclerotium bataticola*. Wilson (1947*a*) did not inoculate seed with *Diplodia theobromae* and stated that the pathogenicity of this organism in causing concealed damage is open to question, but that all evidence points to this logical assumption.

The disease has not been of any importance in the Spanish type peanuts (Higgins, 1944). Wilson (1947*a*) reported that the same has been found true in Alabama.

Control of the disease has presented a rather difficult problem; first, because the exact nature of the disease is not known, secondly because the time of infection has not been established. Garren and Higgins (1947), contending that infection does not occur until after digging, state that control measures are limited to preventing growth of these fungi during the curing process. Wilson (1947*a*) states that in the field the disease is most common in peanuts cured in cocks and that windrow-cured peanuts as a rule contain less damage than stacked or cocked peanuts. Windrowing of peanuts has been suggested by Wilson (1946) and Wilson and Wilson (1945) as means of reducing damage. Wilson (1947*a*) reported that a new variety of peanuts, Dixie Runner, appears to be rather resistant to the disease. Hull and Carver (1945) state that the breeding program of the Florida Experiment Station has resulted in the development of the Dixie Runner variety which appears to be much less susceptible to concealed damage than other varieties. The Florida Runner in 1944 had 6.24 times as much concealed damage as Dixie Runners and 1.58 times as much visible damage. Not more than one percent was found in 30 samples of Dixie Runners in 1944, and in the same locations Florida Runner samples had eight to 20 percent damage.

Concealed damage is one of the major problems in the production of runner peanuts and, as revealed from the material presented above, is a problem on which many more investigations are needed. Any disease which caused two and one-half million dollars damage in Alabama alone in 1945 (Wilson, 1947*a*), with penalties from $25 to $75 per ton to the producer and with no definite indications of exact control measures, is surely a great challenge.

Blue-Black Discoloration

Garren, Higgins and Futral (1947) reported that Spanish peanuts marketed by Georgia farmers are frequently marked down in grade because of a blue-black discoloration of a large percentage of the seed. This disease is not to be confused with "concealed damage", primarily a disease of runner peanuts and discussed in detail elsewhere in this report. In the southwestern United States, which markets predominantly Spanish types of peanuts, this disease has been known as "blue-damage".

As a general rule, when the blue-black

discoloration is noticed, a large proportion of the seeds is affected. They are infected either conspicuously or in such an inconspicuous manner that the infection may be overlooked. The seed coat will usually exhibit discolorations through several shades of blue-black. On the seed coat of one seed may be found spots of many different shades. The discoloration is usually limited to definite spots, or occasionally may be in a form of streaks. When the seed coats were removed from discolored seeds it was found that a considerable proportion of the cotyledons were not discolored, or were faintly discolored. In one lot of 250 seeds 37% were not detectably discolored in the cotyledons, 52% were faintly discolored and 11% were conspicuously discolored. Shell characteristics are associated with the appearance of the seeds, discolored seeds generally having discolored or damaged shells. Shells containing discolored seed produced a mycelium of *Sclerotium rolfsii* Sacc. when placed in a moist chamber. Taste tests indicated that there is no association of a rancid taste with this disease. Neither was germination or chemical composition affected.

Most of the numerous attempts that have been made to isolate a fungus from surface-sterilized discolored seed have been negative. Those that produced fungus were predominantly *S. rolfsii*. In considering possible sources of infectious organisms it was noted that: " (1) *Sclerotium rolfsii* is prevalent in most fields in which Spanish peanuts are grown, (2) *S. rolfsii* was isolated from a few of the discolored spots, (3) *S. rolfsii* grew readily on the shells of peanuts containing blue-black discolored seeds, and (4) it has been shown that the hyphae of *S. rolfsii* secrete oxalic acid and that this acid diffuses into plant tissue in advance of any penetration of the hyphae". From experiments designed to test the hypotheses that *S. rolfsii* is the cause of the blue-black discoloration, it was concluded that the discoloration is the result of an indicator reaction involving the pigments of the seed coat and the oxalic acid secreted by the fungus. While other fungi may sometimes be involved, the prevalence of *S. rolfsii* in peanut fields indicates that it is by far the most important organism associated with the discoloration. Field studies indicate that, in general, the discoloration develops as a result of the saprophytic growth of this pathogen over peanuts during curing.

It was suggested that the most practical method of inhibiting or preventing development of this discoloration in Spanish peanuts is to stack the wilted plants carefully after digging and speed the drying in the stacks if they become wet while curing.

Diseases of Minor Importance

There are a number of diseases of the peanut plant which have been reported from time to time, none of which is of particular economic importance, and their appearance has been sporadic and in isolated areas. The exact relationships of some of these diseases to the peanut plant are unknown, many probably being caused by secondary parasites or saprophytes.

Puccinia arachidis Speg. This rust was reported by Arthur (1920) as being prevalent on peanuts in South America, Trinidad and on nearby islands. It was first noted in Texas by KenKnight (1941). The disease is described by Arthur (1934) as follows: "With pycnia and aecia unknown; uredia chiefly hypophyllous, dark cinnamon-brown, urediospores ellipsoid or ovoid, 16–22 $\times$ 24–29 microns, the wall cinnamon-brown, 1–2 microns thick, the pores 2, nearly equatorial; telia chiefly hypophyllous, chestnut-brown, teliospores oblong often with 3 or 4 cells. 14–16 $\times$ 38–42 microns, germinating at maturity, the

wall chestnut brown, smooth with colorless pedicel, once length of spore; occurs sporadically in southern Georgia and Florida; only as uredia; on *Fabaceae* (*Leguminosae*): *Arachis hypogaea* L.; also in West Indies and South America".

Uromyces arachidis. This rust was reported by Stevens (1917) as being present in South America and the West Indies but was not very common in Puerto Rico.

Parodiella spp. Reported by Viegas (1944) as being found on leaves of the peanut in São Paulo, Brazil, in 1936.

Sphaceloma arachidis Betancourt and Jenkins. Reported by Viegas (1946) from São Paulo, Brazil.

Phymatotrichum omnivorum (Shear) Dug. This organism is the cause of one of the major wilt diseases of cotton, but because of the nature of the soil types in which it is most prevalent, it is of minor importance to the peanut crop. It it found almost entirely in the heavy types of clay soils of the Black Lands of Texas, Alabama and other areas where peanuts, with few exceptions, are not grown. Miller and Harvey (1932) reported that this organism was not isolated in their tests with peanut wilts. Taubenhaus and Ezekiel (1931) report the symptoms of the disease in peanuts to be similar to those in cotton, that is, rapid wilting and death of affected plants, turning black after death. The dead plants are readily pulled out of ground, since the root system is decayed by the root-rot. Loss in fields infected with this pathogen is likely to be total for plants infected, since such peanuts as may be produced, quickly deteriorate.

Phoma spp. This wilt-producing organism was reported by Wolf (1914) as causing stem rot. Miller and Harvey (1932) failed to isolate the organism.

Fusarium vasinfectum Atk. Miller and Harvey (1932) isolated only one colony from a diseased peanut root and stated, "It was not considered as a cause of any of the disease this year, and no experiments were conducted with it".

Diplodia natalensis Evans. Miller and Harvey (1932) stated that the fungus was found in fields in late summer that had been severely infected with bacterial wilt. It appeared to be causing a root rot on ten to 20 percent of the plants in one field. Many plants were still healthy, even though covered with pycnidia at the base. Inoculation experiments failed to produce infection. Since all plants containing *Diplodia* also had *Bacterium solanacearum* in the vascular system as well as lesions on the stems, it was concluded that *Diplodia* was a weak parasite following attacks of more virulent organisms. Viegas (1945) reported *D. natalensis* on peanuts in Brazil.

Phyllosticta spp. Reported by Viegas (1945) on peanuts in Brazil.

Neocosmospora vasinfecta. This pathogen was reported as being found on peanuts by Wolf (1914), but was not considered as being parasitic.

Dry rot. This disease, caused by *Macrophomina phaseoli* (*Sclerotium bataticola*), was reported by Hoffmaster (1943) on peanuts and a tentative control program outlined. The controls suggested included cultural practices that increase crop health and vigor, liming, adding organic matter, and the use of resistant varieties.

Nematodes. The peanut plant is generally considered to be resistant to the root knot nematode or eelworm, *Heterodera marioni* (Skerbakoff and Stanley, 1943). Wilson (1948), however, reported root-knot nematode damage in a field of runner peanuts in Coffee County, Alabama, which was severe enough to reduce the yield to ten percent of that in neighboring fields. Wilson noted that this was the first report of this trouble in Alabama. In 1948 this nematode was observed in a field of Spanish peanuts in Houston County, Alabama, and in

three fields of runner peanuts in Geneva County, Alabama. According to Wilson, "It appears, therefore, that the race or strain of the root-knot nematode that attacks peanuts is now present in Alabama and that it is on the increase". Steiner (1945) reported that the meadow nematode, *Pratylenchus scribneri*, commonly called Scribner's "meadow nematode" is prevalent as a root-destroying agent and has been neglected in nematode investigations. It was reported as causing damage to the peanut pods by discoloration in attacked areas.

Diaporthe phaseolarum var. *sojae*. This organism was reported by Luttrell (1947) as occurring on the stems and stipules of the peanut. Pycnidia develop densely in parallel rows over the entire surface of dead stems, also on dead stipules on yellow moribund stems. The organism is not believed to be the cause of death, but is secondary to other infections, principally *Sclerotium rolfsii*.

Seed Treatment

Seed treatments in the control of disease organisms which attack ungerminated seed after planting and young seedlings immediately after germination have become of increasing importance with the more widespread use of machine-shelled peanuts for seed stocks.

Shaw (1943) states, "There are several conditions or factors which, either individually or collectively, cause poor stands. Studies made during the past several years indicate that one of the major factors causing poor stands is seed decay soon after planting. Such decay may take place on seed having every appearance of healthiness when planted if conditions are suitable for the development of decay-producing organisms during the first few days following planting. Once peanut plants have emerged from the soil a stand is usually assured, because peanut plants are relatively immune from seedling diseases, such as damping off, which affect the seedling stage of many agricultural crops".

The materials suited for seed treatment have been tested in most State experiment stations in the peanut-growing area. All stations have been unanimous in a blanket recommendation that all seed planted be treated.

Beattie and Beattie (1943) state that Arasan, two ounces per 100 pounds of seed; 2% Ceresan, three ounces per 100 pounds of seed; and Spergon, three ounces per 100 pounds of seed, are recommended. Vaughn (1944) states that Arasan at two ounces per 100 pounds of seed was 38% better in emergence percentage than untreated hand-shelled seed, and the same material 100% better than machine-shelled untreated seed. This same investigator ranked Ceresan next to Arasan in effectiveness and Spergon as least effective.

Shaw (1942) reported the results of investigations using 19 chemicals and summarized the results:

Untreated seed	23.2%	emergence
Organic sulphur compound	65.5%	"
Two organic mercury compounds	63.0 and 60.4%	"
Spergon	59.4%	"
20–80 lime-sulphur mixture	52.9%	"

Other copper compounds with 10% copper give medium rank in emergence.

Woodroof (1941), using 2% Ceresan for Spanish peanuts, reported the following results in 1940:

Hand-shelled	82.2%	germination
Hand-shelled, Ceresan treated	88.6%	"
Machine-shelled	50.8%	"
Machine-shelled, Ceresan treated	79.8%	"
Pegs	67.8%	"
Pegs, Ceresan treated	83.4%	"
Not shelled	21.8%	"
Not shelled, Ceresan treated	29.2%	"

Shaw (1943), using seed from different sources and of different sizes, large

and medium, with machine-shelled Virginia Bunch, reported the following average results:

No treatment	49.5%	emergence
New Improved Ceresan ..	77.7%	"
Spergon	92.2%	"
Arasan	82.5%	"
Yellow Cuprocide	60.5%	"

Shaw (1943) recommended the following rates in using the above mentioned materials and indicated the approximate cost for 100 pounds of seed, based on data for treating shelled peanut seed of all varieties:

Material	Rate (100 lbs. seed)	Approximate costs per 100 lbs.
Arasan	**2–3 oz.**	**16¢ to 24¢**
2% Ceresan	**3–4 oz.**	**12¢ to 16¢**
Yellow Cuprocide.	**4**	**12¢**
Spergon	**4**	**50¢**

Shaw, in the same publication, made the following general summary relative to treatment of seed peanuts: "Results of experimental and demonstrational work on peanut seed treatment indicate that this practice offers a means of insuring good peanut stands in a manner similar to that accomplished by cotton seed treatment. Such improved stands will aid materially in economically obtaining the increased production of peanuts".

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Utilization Abstract

Yuca. The elongated tubers of yuca, known also as "manioc" and "cassava" (*Manihot esculenta*), have long been used by natives of South America as a staple food and have also furnished yuca meal for cattle or chicken feed and a wheat-like flour suitable for baking, but for generations the foliage has been discarded. It now "appears that a new food for both human and animal consumption can be made from yuca leaves" and "that in the future yuca may be grown for its leaves while the tubers may become the by-product".

"The first meal, made from leaves collected by hand, was reported by a feed-testing laboratory to be superior in carotene and protein content to alfalfa leaf meal. Even when the entire mature plants were disintegrated and dried they gave a meal with 15.7% protein, equivalent to that of alfalfa meal. The fiber content of yuca plant meal was even below that of alfalfa meal having a similar protein content. In addition, the yuca meal was twice as high in carotene content. . . . Human diets throughout the area in which yuca is grown sadly lack many of the nutritional elements which these leaves contain in abundance. Food processors and home economists soon may utilize these nutritional elements in a form which will be palatable". (W. N. Bangham, *La Hacienda, condensed in Chemurgic Digest 9(10): 10. 1950*).

Ramie. Ramie fiber was used by the ancient Egyptians for wrapping mummies, and the plant was mentioned in the Imperial Chinese Treatise on Agriculture of 2200 B.C. It is thus perhaps the oldest fiber utilized by man and has for centuries been cultivated in the Orient where cheap labor has been available.

Ramie (*Boehmeria nivea*) is a perennial member of the nettle family but without the stinging hairs common among nettles. It sends up tough stalks, five to eight feet tall, and directly beneath the bark of each stalk is a thin layer of this bast fiber which has the following characteristics that make it economically valuable: *a*) in tensile strength it is far superior to cotton and linen, having eight times the strength of cotton and seven times that of silk; *b*) when wet its tensile strength is from 60% to 70% greater than when dry; *c*) it can be combed out almost to the fineness of silk; *d*) it takes dyes well and holds colors better than do most fibers. "Just a few of ramie's possibilities include corduroy that is definitely better than the standard cotton corduroy, inexpensive suits that can't be distinguished from all wool, and conveyor belts and other industrial fabrics for use where 'wet strength' is important. Because it is stronger when wet, ramie also makes superior cordage, fishing nets, and sails. Longer-wearing sheets, pillow cases, toweling (ramie absorbs water even better than cotton does), and draperies as well as bandages, upholstery fabrics, and carpet backing are also on the ever-growing list of uses for ramie fiber. Bank note paper having better wearing qualities than the kind now being used is still another possibility. In fact, it is a matter of sober record that ramie fiber is adapted to the widest range of uses among known textiles".

In spite of these favorable features and millions of dollars poured out in vain to exploit it in Florida and other parts of the world, ramie remains the "'wonder fiber' that never quite made good—a self-propagating crop with an enormous potential that somehow couldn't make the grade".

"The major fly in the ramie ointment, as far as mass production in the Occident is concerned, has been the lack of efficient methods for mechanical decortication. Decortication is the process of removing the bark and pith surrounding the ramie fibers without damaging the fibers themselves. In China, decortication is all done by hand, the workmen scraping the ramie fiber from the green stems with crude implements. In this way, one worker can separate only a few pounds of fiber each day. In our country, of course, any kind of hand process for an operation of this nature would be prohibitively expensive".

"Another trouble has been the cost of harvesting a ramie crop. When growing naturally, some ramie plants mature before others, even though all of them were planted at the same time. Even parts of the same cluster will be of a different height and state of maturity. In the past, this has made hand harvesting obligatory and has practically ruled out mechanical harvesting. Recently, however, careful cultivation and fertilization, the use of superior drainage and water control, and over-all good management have smoothed out this uneven growth. Today, ramie plants cultivated in the United States have an even, steady growth that makes mechanical harvesting practical at last".

Mechanical decortication and degumming still remain to be perfected before successful commercial exploitation is possible and more attention can be given to possible by-products: carotene-containing cattle feed from the leaves and stalks; a salty sauce of meat-like taste for cooking; chlorophyll, xanthophyll and industrial proteins from the "waste"; pectin-containing gum for the food and cosmetic industries as well as others. (E. W. Nelson, *Nat. Hist. 58: 20. 1949*).

Mannitol and Sorbitol. Mannitol is a constituent of manna, the exudation of the manna or flowering ash, *Fraxinus Ornus*, native to southern Europe and largely cultivated in Italy and Sicily. For centuries it has been gathered there and eaten as a mild candy laxative. It has had a similar place

in medicine, and has also been found valuable in the treatment of certain types of high blood pressure, as an ingredient in many special dietary foods, and as a means to prevent caking of various powders and salts, since it does not readily retain moisture. Paradoxically mannitol nitrate is an explosive and has been used in blasting caps.

Sorbitol is an isomer of mannitol and was formerly obtained only from the juices of ripe mountain-ash berries, cherries, apples and other fruits. "Chemists have found sorbitol useful in two ways—as a 'conditioning' agent and as a raw material. One of the most amazing characteristics of sorbitol is its ability to control moisture content of the products in which it is mixed. It holds firmly to water and retards evaporation in dry weather. On the other hand, in damp weather it absorbs water more slowly than other materials used generally for this purpose. So chemists have put sorbitol to work as protection against excessive dryness or moisture in such products as tobacco, printers' rollers, flexible glues, cork, cosmetics, toothpaste, candy and specialty papers, including parchment and glassine".

"Sorbitol has a cool, sweet taste. It is frequently used in mouth-washes and beverages for taste enrichment. Sorbitol is also added to special dietary foods—candies, cakes and chewing gum—making these foods taste more 'natural' even though sugar or some other ingredients have been omitted for dietary reasons".

"Because of its six hydroxyl groups, which are subject to reaction to make new chemicals, industrial chemists have found sorbitol a valuable 'building block'. Combine it with certain fatty acids or with rosin, and you get unusual types of drying oils and resins which help produce superior varnishes. Modify it in another way, and you make vitamin-C".

These two industrially valuable materials, mannitol and sorbitol, formerly obtained as natural constituents of plants, are now being produced synthetically from corn sugar by the Atlas Powder Company. "Back in the 1930's, a whole pound of sorbitol would have been hard to find, and its cost prohibitively high for broad industrial application. Today, Atlas makes sorbitol to sell in carload lots for less than 30¢ per pound". Both sorbitol and mannitol are now being produced by hydrogenation of corn sugar and increasing uses for the substances are being found. (C. D. Pratt, *Chemurgic Digest 9*(7): *4. 1950*).

Maple Flavor Imitations. These manufactured products are based on caramel, coffee extract, lovage oil, fenugreek seed and alcohol. Most imitation maple flavor formulations contain material obtained from fenugreek seed (*Trigonella Foenum-Graecum*), "a leguminous herb which is grown in countries bordering the Mediterranean Sea. The pods that are formed contain many seeds which have a pleasant onion-like odor. An extract is made from the seeds by maceration, using a ratio of about 12 pounds of seeds in a mixture of four gallons of water. The mixture is allowed to stand for about 30 days. Sometimes the oleoresin obtained from this source is used instead of the extract".

"Lovage oil is obtained by distillation from *Levisticum officinale*. It has a heavy odor that blends well with maple formulations. Sometimes the ground root is added to the fenugreek seeds at the time of maceration and a combined extract is obtained. At other times the oil itself is diluted and used in the formulations".

"Other common components of maple flavor formulations are vanillin, coumarin, Peru balsam, hickory bark, celery oil, chamomile oil and musk". (M. A. Jacobs, *Am. Perf. & Ess. Oil Rev. 50: 467. 1950*).

Synthetic Camphor, Menthol, Salicylic Acid. Salicylic acid, necessary in the manufacture of aspirin, can be obtained from oil of wintergreen (*Gaultheria procumbens*), but that natural source is so inadequate to meet the demand that the industry relies upon phenol, a coal-tar product, as raw material. Similarly synthetic camphor has largely replaced the natural product, but in this case the raw material is a plant product. "The manufacture of vulcanite and some plastics can only be satisfied by the production of large quantities of camphor and for this only certain qualities of turpentine are suitable. Germany formerly bought up the output of Pyrenees turpentine to obtain the pinene necessary for the commencement of

the synthesis. Pinene is first converted into iso-borneol from which eventually the camphor is separated, purified and put on the market in the well-known tablets or flowers. Such synthetic camphor is accepted by the British Pharmacopoeia for medical use, and celluloid manufacturers have found it suitable for their purpose".

Likewise the natural supply of menthol from peppermint oil must be supplemented by synthetic production. (Anon., *Am. Per. & Ess. Oil Rev. 41: 120. 1950*).

Carotene and Chlorophyll. "Deep in the Rio Grande Valley of Texas, between McAllen and the sleepy border town of Hidalgo, is a 700-acre farm growing feed stock for a modern chemical plant adjoining it. The feed stock is alfalfa; the products are carotene, chlorophyll, xanthophyll and dehydrated alfalfa meal; the producer is Valley Vitamins, Incorporated, a subsidiary of the Godfrey L. Cabot Company of Boston, Mass."

"Carotene is an orange-yellow fatty pigment or lipochrome which occurs extensively in plants, animal tissue, and in such foods as butter and eggs; it has the formula $C_{40}H_{56}$. It is a member of a class of hydrocarbon pigments called 'carotenes' which owe their color to a long conjugated system of double bonds. All of the hydroxy and carbonyl derivatives of the carotenes, and their combinations, are called 'xanthophylls', and the carotenes and xanthophylls together are classified as 'carotenoids'. The yellow pigment lutein, the xanthophyll found in the leaves of plants, is by structure dihydroxy α-carotene. Largely a mixture of two isomeric compounds, α-carotene and β-carotene, carotene is not only an interesting plant pigment; it is also the parent structure from which vitamin A is formed. . . . Carotene is always associated with chlorophyll in living plants. Although carotene was originally and still is considered as the principal product of the McAllen, Tex., plant, the actual quantities of xanthophyll and chlorophyll are greater. Xanthophyll is not considered an income producer at present; from a marketing standpoint carotene . . . accounts for about the same proportion of income as does chlorophyll".

"Two of the most prolific sources of carotene are carrots and sweet potatoes. Their disadvantage as chemical process raw materials lies in the fact that they are seasonal crops, require more preparation for dehydration than grain crops, and are more difficult to dehydrate. Alfalfa, which is one of the best plant sources of carotene, can be harvested easily and repeatedly without reseeding, and is easy to handle after harvesting. When the processing plant first opened, it used dehydrated alfalfa meal bought from others, but soon began its own growing operations. After considerable trial it was found that the hairy Peruvian strain of alfalfa, from Arizona-grown seeds, is best suited for cultivation in the alkaline sandy clay loam of the Rio Grande Valley. It is possible to get ten cuttings per year, with one cutting produced in 20 to 25 days, except in either cold or very hot weather, when the growing period is a bit longer. Under consideration also when the plant first started operations was the growing of buckwheat because of current interest in the production of rutin. Just as the alkaline soils of the area are favorable to the growth of alfalfa, they are equally unfavorable for buckwheat, so these plans were laid aside. Cheap labor and a plentiful supply of fuel for dehydrating offered additional reasons for the location chosen, and the plant, constructed under difficulties of war shortages, began operations about a year before the end of the war. Because of the urgency of the situation, many aspects of the operation were jumped from laboratory to plant scale without going through pilot plant stages".

"The alfalfa is mechanically harvested and hauled by trailer to the plant, where it undergoes dehydration, the first of three steps necessary before the adsorption process. After the meal is dehydrated, it is extracted in two stages with hexane, and the three pigments, carotene, chlorophyll and xanthophyll, are obtained together in the extract. These are separated by a series of chromatographic adsorption operations and then separately purified".

"Other commercial processes for carotene and chlorophyll separations are essentially solvent extraction processes and depend on selective action of different solvents in individual steps. There are two other plants in the United States which are producing or

have produced carotene, chlorophyll and xanthophyll by these methods—American Chlorophyll, Inc., at Lake Worth, Fla., and Midwest Extraction Company at Rockford, Ill. Operations in both plants are derived from the fundamental work of Willstätter and Stoll and modifications developed by the United States Department of Agriculture. In this later modified method the carotene is extracted with petroleum ether and recovered by concentrating the extract. Chlorophyll and xanthophyll are extracted with acetone and the extract is dissolved in petroleum ether; the major portion of acetone is removed by a water wash, and xanthophyll is separated by extraction with 85% methanol. Chlorophyll is precipitated from the alcohol-washed petroleum ether solution by removing the alcohol with a water wash. Carotene and xanthophyll are purified by recrystallization, and chlorophyll is precipitated from an acetone–petroleum ether solution, with the precipitated material separated by centrifugation. Midwest modifies this method further by evaporation or saponification of the acetone-petroleum solution of chlorophyll, depending on whether an oil-soluble or water-soluble material, respectively, is desired".

"Carotene is produced from carrots by the Barnett Laboratories in Long Beach, Calif., and from palm oil by General Biochemicals, Inc., Chagrin Falls, Ohio".

"General Biochemicals saponifies the palm oil and evaporates the mixture under vacuum, concentrating to a dry finely divided mass. Carotene then is extracted with a suitable solvent".

"The Barnett Laboratories started carotene extraction from carrots on a small commercial scale in 1936. At Long Beach they are centrally located between various large carrot-growing areas, from one or more of which carrots may be obtained throughout the entire year. One of the most important points of the Barnett method is the fact that extraction is done directly and quickly in about five minutes from macerated wet carrots without a dehydration step".

"In addition to its uses as a coloring medium, chlorophyll is reported to have been used in heart therapy and to have definite healing value in some wound cases. Xanthophyll is used to a small extent as an analytical standard, and it has been shown that it is necessary in the diet of laying hens to enable them to produce eggs with yellow yolks".

"Indications are that the carotene market will improve. If pending legislation on the coloring of oleomargarine is favorable to manufacturers there probably will not be sufficient plant capacity in this country to supply the carotene needs for coloring. Carotene is in demand as a vitamin concentrate and as a spectrophotometric, colorimetric, and biological standard. It has been suggested that high purity carotene could be used to enrich food with vitamin A (winter butter, etc., colored with coal tar dyes or annatto extract) if the cost of production can be lowered. At Valley Vitamins, work, based on a modification of the chromatographic technique and now in the pilot plant stage, is expected to produce carotene of greater purity at a reduced cost". (W. H. Shearon and O. F. Gee, *Ind. & Eng. Chem. 41: 218. 1949*).

Florida Fibers. In April, 1947, a Plant Fiber Research Laboratory was opened at the Everglades Experiment Station, Belle Glade, Florida, for the purpose of studying the possibilities of vegetable fiber production in the Southern States. Fifty years earlier a small temporary and short-lived laboratory was set up for similar reasons at Coconut Grove, but otherwise all investigations in the United States on fiber production have been concerned for the most part either with cotton in the South or flax and hemp in the North. About 800,000,000 pounds of jute imported from India have been used annually in the United States for cordage and bagging, and the annual consumption of hard fibers amounts to about 450,000,000 pounds. During recent years the supply of jute has been short because of restrictive planting policies of the Bengal Government in an effort to maintain higher prices and because of replacement of jute acreage with food crops to feed the ever increasing densely populated East. Mexico, Cuba and Haiti have been depended upon for henequen and sisal, and production of abaca was initiated as a war measure in Central America. This dependence upon foreign sources for vegetable fibers calls for studies looking toward domestic production of these plant products,

and it is hoped that something in this direction will emanate from this new laboratory.

Of the 2,000 or more miscellaneous plant species producing fibers that have been utilized by man, only about 30 are of commercial importance. They may be listed as follows with their countries of origin and principal uses:

Stem, or bast, fibers

Flax	*Linum usitatissimum*	Russia, etc.	Textiles
Guaxima	*Urena lobata*	Congo, Brazil	Textiles
Chingma	*Abutilon*	Manchuria	Textiles
Hemp	*Cannabis sativa*	Russia, etc.	Textiles
Jute	*Corchorus* spp.	India	Textiles
Kenaf	*Hibiscus cannabinus*	India	Textiles
Ramie	*Boehmeria nives*	China, etc.	Textiles
Sunn	*Crotalaria juncea*	India	Textiles

Leaf, or structural, fibers

Abaca	*Musa textilis*	Philippines, etc.	Textiles
Cabuya	*Furcrea cabuya*	Ecuador	Cordage
Cantala	*Agave cantala*	Philippines	Cordage
Caroa	*Neoglaziovia variegata*	Brazil	Cordage
Crin vegetal	*Chamaerops humilis*	Algeria	Filler
Esparto	*Stipa tenacissima*	Algeria	Paper, twines
Fique	*Furcrea macrophylla*	Colombia	Sacks
Henequen	*Agave fourcroydes*	Mexico, Cuba	Cordage
Jaumave istle	*Agave funkiana*	Mexico	Brushes
Kittool	*Caryota urens*	Malasia	Brushes
Mauritius	*Furcrea gigantea*	Mauritius	Cordage
Monkey bass	*Leopoldina piassaba*	Brazil	Brushes
Palmetto	*Sabal palmetto*	United States	Brushes
Palma	*Samuela carnerosana*	Mexico	Twines
Palmyra	*Borassus flabellifer*	India	Brushes
Phormium	*Phormium tenax*	New Zealand	Cordage
Piassaba Bahia	*Attalea funifera*	Brazil	Brushes
Sisal	*Agave sisalana*	Africa, etc.	Cordage
Spanish moss	*Tillandsia usneoides*	United States	Filler
Tula istle	*Agave lecheguilla*	Mexico	Brushes
West African bass	*Raphia vinifera*	West Africa	Brooms

Surface fibers

Cotton	*Gossypium* spp.	United States	Textiles
Coir	*Cocos nucifera*	India	Filler, brushes
Kapok	*Ceiba pentandra*	East Indies	Filler
Raffia	*Raphia ruffia*	Madagascar	Twine

Of the above, only cotton, palmetto and Spanish moss are at present commercially handled in Florida; ramie and sisal at times. Coir, flax, guaxima, hemp, henequen, jute, kapok, kenaf, mauritius, ramie, several palms and sunn have been experimented with, as well as pine leaves (*Pinus* spp.), okra (*Hibiscus esculentus*), pineapple (*Ananas sativa*), sansevieria (*Sansevieria* spp.) and yucca (*Yucca* spp.), but there have been in the past several commercial attempts to grow and prepare fibers of ramie and sisal.

"Sisal was introduced into Florida in 1836-1837. Fifty tons of fiber were reported produced at Key West about 1870 and shipped to New York. In 1892 the Florida Fiber Company at Jacksonville planned to devote 1,300 acres to sisal and did set out extensive nurseries of young plants. A cordage mill was built at St. James City on Pine Island, Florida, and some sisal planted near the mill. A planting was made near Goulds in 1916 and additional ones in other localities but no permanent production resulted, and such attempts are history". Attempts to produce

ramie in Florida and other States were carried out before 1900 and similar attempts have been made in Florida in very recent years. Of all the fiber plants tried so far in Florida, ramie seems to be the most promising. But for it and any others, many agronomic, economic and technological problems must be solved before vegetable fiber industries can be developed in the southern States to any major degree. (B. B. Robinson, *Soil Sci. Soc. Fla., Proc. 8: 119. 1946*). (Vol. 8 of 1946 contains the Proceedings of 1947 and was published in 1949).

Sumac Tannin. Technical Bulletin No. 986 (76 pages) of the U. S. Dept. of Agriculture, issued in December, 1949, is a detailed study of the amount of wild sumac available in 18 eastern and southern States as a commercial source of tannin, and is concerned also with the tannin content of this wild material. Of the eight species studied, only *Rhus copallina, R. glabra* and *R. typhina* have sufficiently high tannin content to be of commercial importance; *R. trilobata* might prove of value under certain circumstances; but the remaining four species, *R. aromatica, R. lanceolata, R. microphylla* and *R. virens*, "have objectionable features that would probably prevent their successful competition with the other four species".

The average tannin content of moisture-free leaves of the three best species varied from 25.6% to 36.68%. Date of collecting, height of the plants, shade and sex were found to have some influence on the tannin content; and while the entire eastern United States was considered, "an intensive survey of the quantity of sumac growing wild in an area of approximately 12,000 square miles in the southernmost tier of counties of Virginia indicated that about 43,000 tons of dry sumac leaf would be available there annually . . . an amount equal to at least ten times the normal pre-war amount consumed annually, both domestic and imported". Leaves, leaflets and flowers were high in tannin content; petioles, rachises, stems, bark, wood and seed low. In 1933 sumac dealers purchased more than 640 tons of domestic sumac, and from 1937 to 1944 the amount of domestic sumac used for the manufacture of extract averaged about 1,100 short tons per year.

Before World War II about 60% of the tannin used in the United States was imported, principally from quebracho wood of South America. "The supply of chestnut wood, the present most important source of domestic tannin, is continuously decreasing as a result of the blight" and "much of the sumac now used commercially originates in Sicily, where one species, *Rhus coriaria*, has been grown under cultivation for hundreds of years and is so handled as to produce a material of high quality". American or Virginia sumac, collected primarily in Virginia, smaller amounts in Maryland, West Virginia and possibly one or two neighboring States, has been marketed many years, but is of poor quality in comparison with the imported product. "After importation of Sicilian sumac was stopped by the war in 1941, an effort was made to increase collection of American sumac, but without much success. During the last four or five years, commercial collection of white or smooth sumac, *Rhus glabra*, has been started in Iowa, but it is still in the experimental stage. The reason for the low collection appears to be economic. The market price is high, as compared with that of other tanning materials, yet it is too low to yield an adequate return to labor. Collecting is now done principally by farmers during their spare time or by older persons and children as part-time employment".

"Sumac is used for tanning either in the form of the ground leaf or as an extract. Tanners of light-weight leather value sumac highly because it produces soft, durable, light-colored leathers. Tanners of medium-weight leathers use it for retanning because it lightens the dark color produced by some tanning materials and produces a uniform and desirable feel". It is not suited for heavy-leather tanning.

Domestic sumac as a source of tannin in comparison with Sicilian sumac was discussed in a Federal publication as early as 1869, and in 1872 a shipment to England of 12,000 pounds of sumac from Missouri was reported. (I. D. Clarke, J. S. Rogers, A. F. Sievers and H. Hopp).

BOOK REVIEWS

Forest Products—Their Sources, Production and Utilization. A. J. Panshin, E. S. Harrar, W. J. Baker, and P. B. Proctor. ix + 549 pages; illus. McGraw-Hill Book Co. 1950. $6.

Forest Products—The Harvesting, Processing, and Marketing of Materials other than Lumber, including the Principal Derivatives, Extractives, and Incidental Products in the United States. Nelson Courtland Brown. xv + 399 pages; illus. John Wiley & Sons, New York; Chapman & Hall, London. 1950. $5.

Here are two well-illustrated and equally meritorious volumes on precisely the same subject and with precisely the same principal titles, which differ primarily in their binding, in the former being the work of four instead of one author, and in the former having 150 more pages; the first impression that it is a larger volume in other dimensions is deceiving for the type pages of both are almost equal, the former having wider margins.

Lumber, the leading category of all forest products, is only incidentally referred to in both volumes, for it is so large and highly developed a field of industry as to merit treatment by itself; 60% of all forest products, on the basis of a common measurement factor, is represented by lumber. It is the categories making up the other 40% that are considered in these books.

Under wood products or construction materials there are round timbers, mine timbers, railroad ties, wood furniture, veneers and plywood, wood containers, shingles and shakes, cooperage, fuelwood, pulpwood and others.

The chemically derived and miscellaneous forest products considered in both volumes and listed in the table of contents of each of them are wood pulp and its products, naval stores, wood-distillation products, maple sirup and sugar, and certain extractives. In addition, the larger volume has chapters on "Thermal- and Sound-Insulation Materials", "Cellulose Filaments and Film", "Wood Saccharification" and "Wood in the Plastics Industry" which the smaller does not; and the smaller has chapters on "Rubber", "Excelsior", "Wood Densification", "Charcoal", "Briquettes", "Wood Gas", "Bark (other than for tannin)", "Christmas Trees and Decorations", "Ornamental and Decorative Plants" and "Wild Fruits, Edible Nuts and Tree Seeds" which the larger does not. According to the indices of both volumes, however, nearly every product considered in one of them is at least mentioned in the other, and it is difficult to find any product that has not been at least recognized in both of them. Those topics treated in both volumes are considered in more detail in the larger of them, to such a degree that the index of that volume is twice as long as that of the other.

While both are laden, from cover to cover, with well-presented and abundant information on the many aspects of forest-product utilization, some parts will naturally be of more interest than others to any one reader. The processing methods will be important to some, the economics of the subject to others, and to a third group, which includes the present reviewer, it will be the particular species of trees which furnish the various products and their peculiar adaptabilities to such uses. In the matter of pulp, for instance, Professor Panshin and his associates inform us:

"The three principal materials used in papermaking in the United States are wood, old paper stock, and cotton and linen rags. Other papermaking materials used in this country are jute, hemp, straw, cornstalks, and sugar cane, or bagasse. Of these, wood is by far the most important source of pulp on the basis of the quantity produced. Both conifers and hardwoods are used; the former, however, are utilized to a much greater extent, because of the greater average length of their fibers and the larger percentage of long fibers per given volume of wood. The average length of fibers in a coniferous wood is about 3 mm., that of hardwoods only about 1 mm. The most important coniferous pulpwood species in this country are southern yellow pines, spruces, western and eastern hemlocks, jack pine, and several of the balsam firs. The most important hard-

wood species are cottonwoods and aspen, beech, birch, maple, red and black gums, and yellow poplar. Spruces, which until recently were the leading pulpwood on the basis of quantity used, were superseded in 1939 by southern yellow pines. The consumption of spruce pulpwood has dropped from a high of 76 per cent of the total in 1899 to about 23 per cent in 1939, while that of southern yellow pine has increased from less than 5 per cent in 1919 to more than 35 per cent in 1939 and that of hemlock from less than 13 per cent to 20 per cent ".

On this same point Professor Brown, in discussing the trends in woods used, tells us:

" The total volume of wood used for pulp has steadily increased during the past half century Pulp is one of the few forest products which has not had a reduction in quantity consumed, as have lumber, cooperage, fuelwood, and many other forms. The volume steadily increased from more than 2 million cords in 1900 to twenty million cords in 1948. While spruce has been the premier wood in pulp production, its peak was reached in 1920 with 3,487,598 cords. This amount decreased to about 2,380,000 cords in 1935. Southern pine has had the most notable rise, from 69,000 cords in 1906 to more than 10 million cords in 1948. It seems likely that the consumption of spruce will decline further and the use of southern pine, in the South, will continue to increase. Hemlock has had a steady rise in annual consumption, from about 500,000 cords in 1906 to about 1 million cords in 1925 and close to 3 million cords in 1948. This rise is due to the steady increase in use of the western hemlock in the Northwest, where there has been rapid growth in the installation of mills and the use of this wood for pulp purposes ".

A second forest product on which comparative excerpts from these two books may be made is tannin. On this score the McGraw-Hill text tells us in part:

" The two outstanding sources of tannin used in this country are from the woods of chestnut and quebracho. These two sources account for about 65 per cent of the total amount of tannin consumed. The two sources next in order are eastern hemlock bark and chestnut oak bark, which supply about 20 per cent of the total. Of the four main sources of tannin, three are indigenous to the United States, while quebracho is imported from Argentina and Paraguay. Domestic sources have provided about 55 per cent of our total consumption of tannins, but imports of foreign tannin are increasing steadily ".

Professor Brown has the following to say in part on this topic:

" The most important development in the tanning industry within recent times in the United States came with the discovery of a method of extracting the tannin from the chestnut wood on a commercial basis. The commercial phase of the industry has developed rapidly within the past 33 years, especially in the mountainous sections of North Carolina, Virginia, West Virginia, and Tennessee. In several of the chestnut-extract factories, part of the residue left after the tannin has been removed from the chips is converted into paper. The future of the chestnut-extract industry is not assured, owing to the growing scarcity of chestnut. Of our total consumption of tannin, 50 to 70% is derived from foreign materials. Of these, quebracho wood is the most important, contributing about 40% of our total consumption. Myrobalan nuts, wattle bark, divi-divi, valonia cups, mangrove bark, and a few others together supply the remainder of foreign imports ".

A third comparison of these two books can be made in their final chapters which deal with the minor products of the forest. In this category one volume discusses the bark of cascara, cork oak and Douglas fir trees; the oils, oleo-resins and related products of tung, walnut, juniper, sassafras, birch, balsam and spruce; and the fiber of Spanish moss and redwood trees. The other volume refers among other items to the American annual production of one million tennis, badminton and squash rackets of ash; 335,000 pairs of hickory skis; one million persimmon golf heads; four and one-half million baseball and softball bats of ash; five thousand yew bows; and to the three and a quarter million bowling pins of hard maple.

In concluding this comparative review it may be noted that both books have been prepared as textbooks and have been designed, according to their introductions, to emphasize the principles of forest utilization

without entering too much into the details of the various phases of such utilization. One of them, however, as already indicated, enters into those details to a greater extent than the other and by virtue thereof is more of a reference work and a text for the student who is majoring in forest utilization. The smaller volume is perhaps better suited for a one-semester course, but in no sense is it to be overlooked by the advanced student, for its treatment of the subject is as fundamental as that of the other, without, however, entering into some of the details which the larger volume does.

Forage Crops. Gilbert H. Ahlgren. x + 418 pages; illus. McGraw-Hill Book Co. 1949. $5.

Forage crops, in a restricted sense of the term, are those crops which are harvested by man and later fed to livestock. A great number of species and varieties of economically important plants make up such crops, and in 1947 nearly 61 million acres of land were devoted to their cultivation in the United States, in addition to 14½ million acres producing hay as a wild crop. After teaching courses for many years dealing with these and other farm crops, Professor Ahlgren has produced this textbook dealing with the subject, and in it he discusses their history and development, their geography and production, the influence of climate and of soil upon them. Following the detailed species study, the latter part of the book is devoted to hay mixtures, soil treatments, seedbed preparation, making hay and silage, and other subjects that are common to all forage crops.

Because of difficulties in technique and less economic pressure, progress in breeding forage crops has lagged behind that of grain, fiber and oil crops. There has, however, been some advance in this direction, mostly through selection of superior plants, and such advances as have been achieved with respect to alfalfa, red clover, timothy, bromegrass, Bermuda grass, Sudan grass, sorgos and silage corn are briefly discussed in a separate chapter.

Nearly all the important forage crops belong to either the grass or the legume family. More than 50 species and varieties are mentioned or discussed in the book. Among the grasses are timothy, bromegrass and the cereal crops—barley, oats, wheat and rye; and among the legumes are kudzu vine, soybean, cowpea, vetch and various kinds of clover. These along with the others considered in this volume were harvested in the United States in 1947 to the extent of more than 102 million tons, and their farm value that year was about $1,500,000,000.

Industrial Microbiology. Samuel Cate Prescott and Cecil Gordon Dunn. x + 923 pages; illus. McGraw-Hill Book Co. 1949. 2d ed. $8.50.

The domestic arts of wine making, vinegar production, brewing and the making of leavened bread were practiced by ancient peoples, and by their descendants for centuries after, without any understanding of the processes involved. Not until the fundamental researches of Pasteur less than a century ago did it become known that those processes were the results of living activities of microscopic organisms, but since then knowledge of those processes and of their application to the welfare of man has developed into the science of industrial microbiology. In 1896 the senior author of this volume organized in the Biological Department of the Massachusetts Institute of Technology the first course of classroom instruction in industrial biology given in America, and in 1940 the first edition of this volume appeared under his name. Since then the technological advances in this field have been so great that the present revised edition has been issued, with original chapters re-written and five new ones added. The result is an encyclopedic volume of great scope to serve as a text for advanced students and as a work of reference.

While the term "microbes", in its broadest sense, refers to extremely small organisms of both plant and animal natures, *i.e.* including protozoa, spirochetes and minute parasitic worms, "a modern tendency apparently is to confine the term 'microbiology' largely to organisms that fall within the realm of the lowest groups of botanical or plant life. It is in this sense that the word is used in this book". These microscopic groups of plant life that are of industrial import today are the yeasts, molds and other low fungi, and several groups of bacteria.

In the majority of cases, utilization of these organisms involves a fermentation process. Both yeasts and bacteria serve in this capacity. The former are the fermenting agents utilized in the manufacture of ethyl alcohol for industrial use and of the beverages beer, ale, porter, stout, wine, rum, whiskey, brandy, gin, cordials and liqueurs. Yeasts also serve in a secondary method of producing glycerol, which has many uses in industry and in the arts, and, of course, as the fermenting agent of baking. Various strains of yeast are used for these different operations, but most of them have been derived from the two species *Saccharomyces cerevisiae* and *S. ellipsoideus*. The industrial operations in which various kinds of bacteria are the fermenting agents include the manufacture of butanol, acetone and ethanol; acetic and butyric acids; and carbon dioxide and hydrogen gases. More than 30 different products are obtained by such bacterial fermentations. Molds, more particularly strains of *Aspergillus niger*, are used in three important industrial fermentations, those yielding citric, gallic and gluconic acids; others can be used to produce fumaric, itaconic, itatartaric, kojic and lactic acids.

Molds may also be used to produce four principal types of industrially important enzymes: amylases, useful " in the preparation of sizes and adhesives, in the desizing of textiles, for the removal of starch from apple pomace in the manufacture of pectin, in the pharmaceutical trade, and for other purposes "; invertase, " used in the confectionary trade for the making of soft centers in chocolate-coated candies, for this enzyme converts sucrose to a mixture of glucose and fructose "; proteases, " which may be used in the degumming of silk goods, in the unhairing and bating of hides, in the manufacture of liquid glue, as a substitute for or combined with soap in the laundry business, and as an agent in the ripening of cheese "; and pectinase, which " may be used to aid in the clarification of fruit juices ".

In addition to serving as fermentation agents, yeasts have been utilized to produce human food and animal fodder. Food yeast is a rich source of proteins and vitamins of the B-complex, and the manufacture of it provides a means of utilizing waste, surplus or low-cost carbohydrate materials as nutrient media. Among the many materials that may be used in this manner are waste sulphite liquor, acid-hydrolized wood, molasses, hydrolized grains, citrus fruit waste, wood sugar stillage and carob beans. *Torulopsis utilis* is the yeast most frequently used, but other species of this genus and members of other genera have also been found useful. " Food yeast was manufactured and used to some extent by the Germans during World War I. Several thousand tons were produced and consumed during World War II, the raw materials being sulphite liquor or wood hydrolyzates. The Colonial Office of Great Britain undertook the construction of a large plant in Jamaica for producing food yeast early during the latter war. India is much interested in this subject, as are other countries ".

The longest chapter in this book—101 pages—deals with the antibiotics produced by Actinomycetes, bacteria and fungi. Penicillin is naturally accorded extensive treatment, but more than 75 other substances are also discussed or at least mentioned. Finally there are chapters on the microbiology of textiles and of wood, in which consideration is given to the bacteria and molds which damage cotton and wool, and are important in the process of retting; and to those responsible for the destruction of wood.

There is also the matter of saccharification which is the process of hydrolyzing starches, hemicelluloses and celluloses to fermentable sugars by means of enzymatic or chemical agencies, or a combination of both, before those substances may be used for certain industrial purposes, such as ethanol production. Most important of the chemical agencies are hydrochloric and sulphuric acids, used in connection with grains; vegetables; agricultural residues, such as corncobs, cotton-seed hulls, flax shives, oat hulls and sugar-cane bagasse; and wood. Enzymatic agencies are malt, which is of cereal origin; and those of microbial origin, among which are mold and bacterial products. Malt is the product obtained by steeping selected barley, allowing it to germinate to a certain degree and then drying it, as a result of which the hydrolyzing enzymes are produced and stored in the germinated grain. " Malt has many uses. It is used extensively in the brewing industry as the chief raw material

in the manufacture of beers and ales; and as the saccharifying agent in the manufacture of industrial alcohol and distilled liquors from grains. Malt is also used in the manufacture of malted milk, candies, cereals, and food colorings but is usually roasted first in special ovens under carefully controlled conditions". The enzymes naturally occurring in wheat may also be utilized as well as mold bran which is an enzyme product obtained by growing *Aspergillus oryzae* on moist sterilized bran.

Alcohol production is one of the best known and most important of all industrial fermentations, involving the conversion of sugars into ethyl alcohol, known also as ethanol. Many kinds of raw material are used, including the conversion sugars noted in the foregoing paragraph, but the principal ones are molasses and grain. While other yeasts are also employed as the fermenting agents, it is mostly strains of *Saccharomyces cerevisiae* that are utilized.

Each of the foregoing processes and many others are described in considerable detail in this volume which probably contains between its covers more information on the industrial utilization of the microscopic forms of plant life than any other single book.

The History and Social Influence of the Potato. Redcliffe N. Salaman. xxiv + 685 pages; illus. Cambridge Univ. Press. 1949. $12.50.

When it is borne in mind that nearly this entire volume, 562 pages to be exact, is devoted to the history of the potato as a source of human food and to the influence which it has exerted on social development during 450 years, it becomes very apparent that this commonplace edible tuber has indeed been an economically important member of the plant world. Beginning with its archeological record in America the author of this impressive volume traces that history through the Inca period and introduction into Europe, to its role in the economy of peoples in the British Isles and elsewhere. Separate chapters are devoted to Ireland, Scotland and other parts of Great Britain, but only incidental mention is made of the potato in the United States; so little, in fact, that one not knowing better might get the impression that the potato has been of no importance in America since it was discovered here.

The principal use of potatoes has of course been as a source of food—for both human consumption and as stock-feed. "In general, on the continent of Europe, some 20–50% of the potato production is normally fed to stock, while in Eire, almost 60% of the potato production is used for stock feeding. In England and the United States, on the other hand, the use of potatoes as stock food is not nearly so important as their use for human consumption". In addition to such food uses, including potato flour, the potato "provides a readily obtainable but uneconomic source of starch or the products which may be produced from starch. Its disadvantages as such (due to the high proportion of water it contains) are partially offset—though not from the manufacturer's point of view—by the fact that, in temperate climates it yields more starch per acre than any other crop. The importance of this varies with the economic conditions peculiar to the different countries, and the availability of alternative raw materials. In the British Isles and the United States of America the potato has been almost disregarded as a raw material, but it is extensively used in Russia and continental Europe. . . . Of the world's production of potatoes a greater proportion is probably used for stock-feeding than for any other single purpose, closely followed by the proportion used for human consumption".

"Starch is extracted by breaking the cell walls, either mechanically or by digestion with *Bacillus felsineus*, washing the starch free of cell debris and then drying it. Potato-starch is particularly suitable for sizing paper and textiles, and is the type of starch most frequently used for finishing fine cotton goods, but it may be put to many other uses".

"Dextrins and British gums are produced by roasting acidified starch. They are used as adhesives, for sizing textiles, and as constituents of textile printing inks".

"Dextrose and commercial glucose are prepared by the acid hydrolysis of starch. . . . Commercial glucose is used in tanning, and in the food industry, while pure glucose may be used in the preparation of pharmaceutical products".

Finally, as industrial products derived from potatoes, alcohol may be prepared by fermentation of a cooked mass by yeast, followed by distillation; and acetone may be produced by bacterial fermentation of starch-containing vegetable products, such as maize.

The Actinomycetes—Their Nature, Occurrence, Activities and Importance. Selman A. Waksman. xx + 230 pages; illus. Waltham, Mass.: The Chronica Botanica Co.; New York City: Stechert-Hafner, Inc. 1950. $5.

The Actinomycetes are microscopic, branching, unicellular organisms, intermediate between the true fungi and the true bacteria, which attracted only academic interest until January, 1944, when Dr. Waksman, the author of this volume, announced the discovery made by him and his colleagues that one of these organisms can be used to produce an antibiotic efficacious in combatting some of man's diseases. That was the discovery of streptomycin. Since then other chemotherapeutic agents have been obtained from these organisms, most important of which have been aureomycin and chloromycetin, and the possibilities of other medicinally valuable agents among these lowly organisms is being explored. It is fitting, therefore, that the man who has been so prominently associated with this development should now present a volume discussing the entire biology and economic importance of the Actinomycetes.

Some of these organisms are the causative agents of disease in plants, in man and in his domesticated animals; and the possibility of obtaining enzymes and vitamins from them has been explored. In this respect Dr. Waksman has the following to say:

"Comparatively little use has been made so far of actinomycetes for production of chemical compounds that find application in industry or in nutrition. Only one attempt has been made to use the diastatic enzyme of an actinomycete; this has been produced under the name 'superbiolase' because of its ability to withstand higher temperatures than the corresponding enzymes of barley and of certain microorganisms. Of much greater importance is the recent finding that certain strains of *S. griseus* (grisein-producing) are capable of producing vitamin B_{12}. The red crystalline material isolated from these cultures had all the properties of the compound isolated from liver".

Regarding the well-established utilization of these organisms, Dr. Waksman has the following to say in summary:

"Among the various groups of microorganisms that have the capacity to produce antibiotic substances, or agents which have the capacity to inhibit the growth of and even to destroy bacteria and other microorganisms, the actinomycetes occupy a prominent place. Within the last seven or eight years nearly 30 antibiotics have been isolated. They vary greatly in their antibacterial properties or in their antibiotic spectrum, in their chemical nature, in their toxicity to animals, and in their chemotherapeutic potentialities. Some, like actinomycin, are highly toxic; others, like streptomycin, possess only a very limited toxicity. Some are produced by more than one organism; and some organisms produce more than one antibiotic".

"Of the various antibiotics produced by actinomycetes, streptomycin occupies a leading place. First announced in January, 1944, it was used clinically within less than two years. Among its most striking properties are its action against Gram-negative bacteria and the bacteria causing tuberculosis. Thus, a chemotherapeutic agent that has marked effects against the 'white plague' of man has been discovered. What appeared only a few years ago to be one of the greatest scourges affecting millions of human beings has been subjected to control by the product of an actinomyces. Within five years after its announcement, the production of this antibiotic has risen to nearly eight million grams per month".

"Some of the newer antibiotics, notably aureomycin and chloromycetin, have also attained remarkable production records".

"The possibility of discovering other antibiotics that would supplement streptomycin or take a place by its side as an important therapeutic agent appear very promising. Although some agents, like streptothricin, appear to be too toxic to offer great immediate promise, others, like grisein, are highly active and possess only very limited toxicity. These, therefore, appear promising".

"Thus, the actinomycetes have contributed important tools for combating human and animal infections. The end of these possibilities is not yet in sight. Of what significance these reactions are to soil processes still remains to be determined".

"The actinomycetes can take their place among the major groups of microorganisms affecting the economy of man in numerous ways. Their importance in the cycle of life in nature and in the control by man of natural processes can hardly be exaggerated".

Bananas. H. W. von Loesecke. Interscience Publishers. 189 pages. 1949. $4.50.

As Volume I in a new series of books to be known as "Economic Crops", and with 38 of its pages devoted to the history and botany of bananas, this little volume is concerned primarily with the chemistry, physiology and technology of these well known fruits.

In commercial practice bananas are never allowed to ripen on the tree, but are always gathered while still green, and are ripened by various means. In India this procedure may involve only smoking, but in more progressive countries it is carried out under controlled temperature, humidity and ventilation to prevent excessive accumulation of carbon dioxide. Ethylene gas and other agencies have been employed to accelerate ripening. Their use and the chemical changes occurring in the banana during ripening are described, as well as means of transportation.

Banana products include what are referred to as flakes, figs, powder, flour and jam, but their manufacture is not of great economic significance except perhaps locally; in 1944 about 30 million bunches, or 1½ billion pounds, of bananas were imported into the United States but only about 1½ million pounds of dried bananas, or less than 0.1% of the bunches imported. More important are the general nutritive value of bananas and their specific worth in treating celiac disease.

Apples and Apple Products. R. M. Smock and A. M. Neubert. Interscience Publishers. xvi + 486 pages. 1950. $7.80.

This book, which is Volume II of the publishers' "Economic Crops", is believed by its authors to be the first book devoted to the apple subsequent to harvest, and as such it is not at all concerned with the production aspects of this fruit. After the first chapters on the history and distribution of apples, on the more than 1800 known varieties, and on the development and structure of the fruit, a major portion of the volume is devoted to its chemistry, physiology and technology. Processing and utilization of apples is primarily a food industry because the relatively high cost of producing the fruits renders them uneconomical sources of raw materials in non-food industries. "In the United States the quantities of apples processed annually during the period from 1934 to 1944 inclusive varied between twenty and thirty-five million bushels, representing from 19 to 30% of the total commercial crop. Slightly over half of this fruit was used in preparing canned, dried, and frozen apples. The remainder was used in the manufacture of apple juice, vinegar, fermented beverages, and miscellaneous food products.

In addition to their great food value and usage in a variety of ways, apples are potential sources of malic acid from their juice and of wax from the pomace left after juice extraction. These products, however, are not in commercial production; the only one that is commercially produced is pectin obtained from the pomace.